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ENVIRONMENTAL SURVEY—TAR SANDS IN SITU
PROCESSING RESEARCH PROGRAM (VERNAL,
UINTAH COUNTY, UTAH)

By
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FORWARD

This Environmental Survey is intended to serve as a guideline for the consideration of environmental consequences of on-going research in tar sand in situ processing conducted by the Laramie Energy Research Center (LERC) near Vernal, Utah. The document is not a part of LERC compliance with the National Environmental Policy Act (NEPA) and should not be construed as such. However, it is used for input to NEPA documents and research planning.

The document was prepared by the University of Wyoming's Rocky Mountain Institute for Energy and Environment for LERC's Office of Environment and Conservation.

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CHAPTER I

DESCRIPTION OF PROPOSED ACTION

A. INTRODUCTION

1. IN SITU COMBUSTION PROCESS RESEARCH

The Laramie Energy Research Center proposes to continue ongoing research on in situ recovery of oil from tar sands. Research has been conducted on a parcel of land that takes up approximately 6 acres. The land is owned by Standard Oil of Ohio (SOHIO). Specific near term research involves the second tar sands in situ oil recovery field experiment, scheduled to commence late in FY 77. LERC proposes, in addition to completing test #2, to prepare for and ignite test #3 to prove the technical feasibility of reverse-forward combustion in hydraulically induced fractures. LERC anticipates completing test #3 in FY 79 and to prepare for test #4 to prove the technical feasibility of reverse-forward combustion in a high-capacity fracture system. Test #4 is expected to be ignited in FY 80 and completed in FY 81. The objective of the LERC tar sands project is to determine the technical feasibility of using in situ combustion for the recovery of oil from U.S. tar sands, and to develop designs for a large-scale field demonstration of the economic feasibility.

Known tar sand deposits in the United States contain an estimated 30 billion barrels of oil. Efforts to develop production technology have been unsuccessful probably because of the high costs involved and the low price of oil. The increasing demand for oil and decreasing

domestic supply have renewed interest in finding means to produce the oil. Oil is being produced commercially from the Athabasca tar sand deposit in Alberta, Canada. Strip mining and above-ground extraction of the oil are used. Significant efforts are also being made to develop in situ methods suitable for the Athabasca deposit, but little or no data are being released.

The characteristics of tar sand deposits in the U.S. are quite different from those in Alberta. Over 95 percent of the presently known U.S. resource is in Utah. There, six giant deposits, ranging in estimated resource from 1 billion to as much as 16 billion barrels, are considerably smaller, are spread out over larger areas, and have much thinner, harder, and more consolidated tar sand zones than the Canadian deposits. Moreover, the domestic tar sands generally have much lower water saturations than the Canadian deposits and are considered to pose different problems in separation of the bitumen from the rock.

Since about 80 percent of the tar sands lie under overburden too thick for economical strip mining, in situ recovery methods will be required if significant production is to be developed. This project was begun in FY 71 with initiation of a continuing investigation of the characteristics of U.S. tar sands. In FY 73 investigation was made of in situ recovery methods that offered promise for development of a method for tar sands. That investigation showed definite advantages for thermal recovery methods and particularly for in situ combustion because little water would be required in the water-scarce, semi-arid areas of Utah. Reverse combustion (see Figure 1) was selected for field testing after laboratory tests of low-temperature oxidation showed auto-ignition would not be a problem. Laboratory combustion-tube tests provided data for

FIGURE 1.
IN SITU TAR SANDS RECOVERY PROCESS

THE BITUMEN (OIL) IS IGNITED AT THE PRODUCTION WELLS ①. THE COMBUSTION FRONT THEN SPREADS TOWARD THE AIR INJECTION WELLS AS IT MOVES OPPOSITE THE DIRECTION OF THE AIR FLOW ②. THIS REVERSE COMBUSTION STAGE IS FOLLOWED BY A FORWARD COMBUSTION BURN (NOT ILLUSTRATED). THE TAR SAND FORMATION IS NOW HEATED ENOUGH TO PERMIT THE BITUMEN TO FLOW INTO THE PRODUCTION WELLS WHERE IT IS PUMPED TO THE SURFACE.

THE FLUIDS PRODUCED WITH THIS METHOD ARE RECOVERED AS VAPOR WHICH IS CONDENSED AND SEPARATED INTO OIL, GAS AND WATER.

design of test #1, involving reverse combustion alone. Test #1 produced about 70 barrels of oil before unexpected production of viscous bitumen, which plugged surface equipment, forced termination. The results showed that only a 1- to 2-foot interval was burned through, but this served to heat the rest of the zone, making the bitumen mobile.

Test #2 was designed to test reverse combustion through a permeable zone for heating adjacent richer tar sand from which bitumen could be recovered by forward combustion. Bitumen mobilized, as in test #1, will be kept hot by heat tracing in production equipment so that the reverse combustion phase can be followed by forward combustion and a more efficient recovery of the bitumen. Test #2 should be completed by mid FY 78. General application of the concept of preheating with reverse combustion will probably require burning through induced fractures rather than the chance occurrence of a permeable zone. Research on burning in fractures with preliminary field fracturing tests is scheduled for late FY 77 and early FY 78. Test #3 of in situ combustion utilizing induced fractures is anticipated to begin in FY 78.

2. PROPOSED STEAM INJECTION EXPERIMENTS

LERC also proposes to commence a field project that will determine the technical feasibility of using steam in situ recovery technology to recover oil from U.S. tar sands and to perform a field demonstration of the economic feasibility of recovering oil from the tar sands by this means.

Some of the most important problems affecting use of steam and the development of satisfactory in situ recovery procedures are:

Fluid injectivity, or the lack of it, in highly bitumen-saturated rock poses a considerable problem. Possible solutions may be found in fracturing the formation or in steam stimulation to remove bitumen and

increase permeability near well bores.

Congealing of bitumen upon cooling when the bitumen is displaced into the unheated part of a tar sand may restrict or interrupt flow through the tar sand. Possible solutions that should be investigated are, again, fracturing to increase initial fluid transmissibility or the use of solvents to reduce the effect.

Obtaining sufficient temperature by steam injection at lower pressures required for shallow depths. Possible solutions include the use of solvents or other chemicals to enhance the viscosity-reducing effect of the temperature increase provided by steam.

Other problems should surface as efforts to apply steam to tar sands are made. For instance, the nature and extent of subsurface environmental impact from alteration of bitumen chemistry with high temperature must be determined and means to minimize these effects sought.

In more detail the project is proposed to begin in 1978, with laboratory investigation of stimulation/steam "huff and puff" applicability to domestic tar sands. Laboratory investigation of enhancement of the steam processes by solvent addition to assist in lowering of bitumen viscosity and consequent reduction of injected steam temperature and pressure will be initiated. In addition, development of computer models to describe and predict behavior of steam processes will be initiated.

In FY 79, LERC will, under the proposed program, select and initiate preparation of a site for the first steam field experiment, determine the steam process to be investigated, and initiate engineering design of the process.

In FY 80, LERC proposes to continue development of computer models to describe and predict behavior of steam processes; complete preparations for and conduct of (including environmental monitoring) and

initiate evaluation of the first steam field experiment, initiate the economic assessment of the process employed in the first experiment; and initiate planning and preparations for the second steam field experiment, including the engineering design and environmental assessment.

In future years, through 1985, LERC proposes to complete a series of at least three steam field experiments, the last of which will be a "commercial" demonstration, with related laboratory development, engineering, and environmental support.

3. A PLAN FOR A DOE TAR SANDS PROGRAM

LERC is preparing a program that will address all aspects of tar sands recovery in the U. S. LERC proposes to submit this plan to ERDA Headquarters for consideration. The program will include a plan for research, through commercial demonstration, on true in situ, modified in situ, and mining with surface processing technologies. The elements of the program include efforts to define the resource base, conduct laboratory development, demonstrate the technology through a commercial demonstration, prepare engineering reports, prepare an environmental plan that will move along with the technology development, and finally organize a legislative effort that is designed to address legal constraints which discourage industry from involving itself with tar sands development.

5. TAR SANDS DEFINITION

Tar sands, oil sands, bitumen-bearing rocks, oil-impregnated rocks, and bituminous sands are terms used interchangeably in the

study to describe hydrocarbon-bearing deposits distinguished from more conventional oil and gas reservoirs by the high viscosity (thick or glutinous character) of the hydrocarbon, which is not recoverable in its natural state through a well by conventional oil production techniques. Oils from tar sands are chemically similar to some crude oils: upgrading is required to convert them to a refinery feed stock. Many Utah tar-sands oils, particularly those from the Uinta Basin, are similar to good grade paraffinic oils. ("Energy from U. S. and Canadian Tar Sands: Technical, Environmental, Economic, Legislative, and Policy Aspects," Report prepared for the Subcommittee on Energy of the Committee on Science and Astronautics U. S. House of Representatives, 93rd Congress, 2nd Session, p. 7.)

B. CONSTRUCTION PHASE

1. ROAD CONSTRUCTION

a. In Situ Combustion Process Research

Roads have been constructed into the field site. Access roads to the location were prepared from existing dirt trails and improved by grading for drainage and graveling.

b. Proposed Steam Injection Experiments

The selection of a site for field experiments is not expected to occur until FY 79. Consequently, it is too early to identify roads that will need to be constructed.

c. Proposed DOE Tar Sands Program

A program that will involve surface mining and underground mining may require extensive road development. Roads will be required that will handle heavy machinery, equipment, and large volumes of traffic. Future EIA's will address the associated impacts and will be used for choosing field sites.

2. UTILITY CORRIDORS

a. In Situ Combustion Process Research

The existing field site uses power generated off site by Utah Power and Light. Telephone communications are used. A telephone line was run into the site from existing lines. No other utility lines or corridors are in use.

b. Proposed Steam Injection Experiments

A site for these experiments will be selected in FY 79. It is possible that power will be generated on site. Telephone communications will be served by radios, telephone lines, or microwave facilities. Requirements will be determined and alternatives will be discussed as part of a later EIA.

c. Proposed DOE Tar Sands Program

A proposed program that includes mining of tar sands will require corridors to be planned for gas lines, power lines, water lines, and

possible telephone lines. If the proposed program is adopted, future EIA's will discuss the detailed impacts associated with alternative sites.

3. SITE CLEARING

a. In Situ Combustion Process Research

The 1974 EIA ("Draft Environmental Assessment") said that the current 10-acre site would be used for several experiments which would cover 1 to 2 acres. Approximately 6 acres was fenced in for the research site, and the topsoil was stockpiled from approximately 4 acres which were cleared. The acreage is being used for a compressor building, a production building, cooling- and heating-water ponds, heat-traced oil production lines, and three 300-bbl tanks (two for oil and one for water). LERC's test #2 will be conducted on the same land that was cleared for test #1 (Figure 2). It is anticipated that test #3 and test #4 will require clearing of the remaining 6 acres of the 10-acre site.

b. Proposed Steam Injection Experiments

Preparation of a site for steam injection experiments is expected to begin in 1979. Two experiments are planned. The first will actually be run in 1980, and preparation for the second will be started in 1980. These experiments will require clearing of approximately 10 acres total. Topsoil will be segregated and stockpiled. Selection of the site will not occur until 1979, and the selection alternatives will be covered by a later EIA.

c. Proposed DOE Tar Sands Program

The proposed DOE tar sands program includes technology demonstration of true in situ processes through the first five years, with

FIGURE 2. - LERC TAR SAND FIELD EXPERIMENT SITE.

commercial demonstrations running from the beginning of the third year through the eighth year. The true in situ combustion research under this program includes two field experiments of approximately 6 months' duration in the first year and one lasting approximately 16 months, beginning in the third year. These three experiments would require that between 10 and 15 acres be cleared. The true in situ research, using hot fluids, steam drive, and solvents, consists of one experiment lasting for 5 months, beginning in the third year. The test will require clearing between 5 and 10 acres. A true in situ experiment using a combination of forward combustion and water or fluid injection is proposed to run for one year, beginning in the fourth year. This test would also require clearing of approximately 10 acres.

In summary, then, true in situ experiments utilizing various combinations of technologies will require the clearing of between 25 and 35 acres of land for the experimental sites themselves. It is important to note that the combustion and steam drive technologies may not necessarily involve experimental sites different from those already discussed in Sections 3.a and 3.b.

The "Proposed DOE Tar Sands Program" includes modified in situ research. The modified in situ process involves mining to create void space, followed by explosive fracturing of the surrounding formation into the mined-out area. This process is designed to create a porous volume through which gases and liquids can flow without significant obstruction. The process would require the clearing of several acres to provide space for the stockpiling of mined-out material, as well as the clearing of 10 to 20 acres of land for surface equipment. Land will also have to be cleared for a mine bench. Three field experiments are planned

under the program. One would run from the second year (construction) to the sixth year (start up and retorting). The second experiment would run from the third year to the sixth year. The third would run from the second year to the sixth year.

The program includes research on mining with surface processing. Site selection and mining tests would run from the first year through the seventh year under this program. Surface facilities would require the clearing of 10 to 20 acres of land. Additional land would be required to stockpile mined material. The acreage involved here could require up to 100 acres, depending upon the volume to be mined.

It is important to note that the above figures are very rough since the ideas are being proposed at these early stages, and detailed plans will have to be made in the future. It is also important to note that site selection has not been made, and is dependent upon acceptance of the "Proposed DOE Tar Sands Program" by DOE Headquarters.

4. BUILDING CONSTRUCTION

a. In Situ Combustion Process Research

No permanent buildings are constructed on field sites. As stated earlier, the present site houses a compressor building and production building. They are temporary in nature since the experiments are of short duration and it is most feasible to move buildings from site to site.

b. Proposed Steam Injection Experiments

The proposed steam injection experiments, small in nature, will also require a small number of temporary buildings to house steam generators, computers, and production equipment. They will be located on the same land that has been cleared for the experimental site.

c. Proposed DOE Tar Sands Program

All buildings associated with the proposed program will be temporary in nature. Buildings associated with the true in situ experiments will be the same as those listed above.

Modified in situ experiments will require similar facilities for production equipment. In addition, buildings related to mining operations will be required. The buildings, temporary in nature, will be necessary to house mining equipment and crushers; a garage will be necessary. Since a large number of workers will be needed to carry out the mining operation, buildings may be required for such things as dormitories, cafeterias, change rooms, and offices. It is anticipated that all of these buildings would be temporary in nature.

Building requirements for surface processing associated with mining will be similar to those required for modified in situ research.

5. HOUSING AND EQUIPMENT INSTALLATION

a. In Situ Combustion Process Research

LERC employees and contractors are used to construct buildings and install equipment; LERC employees on the site number between 5 and 15. Contractors (less than 10) are on site for a few days at a time. Contractors and employees are housed in motels in Vernal, Utah. LERC employees commute to and from Laramie. On-site permanent housing is not required for any employees.

b. Proposed Steam Injection Experiments

The steam injection experiments will be run similar to the reverse combustion experiments.

c. Proposed DOE Tar Sands Program

True in situ experiments will have the same requirements as those listed above. Modified in situ and mining experiments associated with surface processing could require up to several hundred employees during the construction phase. It is impossible to determine exact numbers until detailed experimental design gets underway. Trailer courts, dormitories, or possibly permanent housing will be required for these people. Requirements will depend upon the location, size, and duration of the experiment, as well as the labor availability in the local population. If the experiments are conducted in Utah, it is possible that local labor markets and facilities will be insufficient to supply the needs of the experiment.

6. WELL DRILLING

a. In Situ Combustion Process Research

The 1974 EIA (Interior Dept., "Draft Environmental Assessment") proposed that "fifteen wells would be drilled, cased, cemented and connected to air compressors, production treating equipment and instrumentation, by surface pipelines and electrical conduit on each experiment." Tests #2 and #3 will consist of between 10 and 22 wells. The wells included six injection wells, three production wells, and six monitor wells for temperature monitoring over a 120' x 40' pattern. However, additional groundwater-monitoring wells will be necessary in order to conduct adequate environmental research. The number of wells will depend upon adequate funding for environmental research and the needs for such research on tests #2 and #3.

b. Proposed Steam Injection Experiments

Well requirements for steam injection experiments will be similar to those for in situ combustion research. Groundwater monitoring will require additional wells. The exact number will depend upon the site location, its characteristics and funding.

c. Proposed DOE Tar Sands Program

Well requirements under the proposed program for true in situ research will be similar to those for in situ combustion and steam injection experiments described above. Water-monitoring wells will be required for modified in situ experiments. In addition, production and injection wells are required for modified in situ research. The exact number will depend upon experimental design. Mining with surface processing will involve surface or underground mining depending upon the site location. The extent of mining is not known until experimental design takes place. Again, it is noted that surface processing and modified in situ research are being proposed for ERDA Headquarters consideration at this time.

7. GEOLOGIC FRACTURING

a. In Situ Combustion Process Research

Research on burning in fractures with preliminary field fracturing tests is scheduled for late FY 77 and early FY 78. Test #3 on in situ combustion utilizing induced fractures is anticipated to begin in FY 78. Fracturing will be accomplished either hydraulically or with chemical explosives. The purpose is to create the permeability required for fluid flow over a desired path through a tar sand zone.

b. Proposed Steam Injection Experiments

In FY 79, LERC proposes to initiate preparation of a site for the first steam field experiment. One of the most important problems affecting use of steam and the development of satisfactory in situ recovery procedures is the lack of fluid injectivity. Steam injection near the well bore is a potential way for increasing permeability by removing bitumen. Steam injection combined with fracturing could further enhance permeability. Experimental design work prior to field operations will dictate experimental work in the field.

C. OPERATIONAL PHASE

1. PROPOSED PROCESSES

a. In Situ Combustion Process Research

"Air is injected through a well and moves through the formation [tar sand] to a production well. Ignition of the oil [in reverse combustion] is obtained by heating the formation in the production well. [Ignition occurs in the injection well with forward combustion.] The burning front is then propagated through the formation toward the injection well in a direction reverse [reverse combustion] to that of the injected air flow and at a rate dependent upon the air flux and temperature of the burning front. Vaporized and cracked hydrocarbons and combustion products flow from the burning front in the same direction as the air, through the hot, previously burned formation to the producing well and are produced to the surface. There the production stream is cooled and separated into oil, water, and gas in surface facilities." (U.S. Bureau of Mines, Department of the Interior, May 1974.)

"Vapors produced from the . . . wells may be as hot as 500° to 800°F. They . . . pass through a two-phase separator where, as a result of air cooling, some components of the oil may be condensed and collected, then through a water-cooled heat exchanger for cooling at about 100°F. From the heat exchanger the fluids . . . enter a three-phase separator for separation of gas, oil and water. Vapor from this separator [passes] through an electrostatic precipitator for removal of oil mist, and [is] then vented to the atmosphere through a stack. Produced oil and water [are then] pumped to storage tanks. Two complete separator facilities are provided to permit continuous production as well as independent flow testing." (Cupps, Land, Marchant: LERC.)

b. Proposed Steam Injection Experiments

LERC proposes to conduct a series of experiments using injection of steam into a tar sands deposit. The process to be studied will not be determined until FY 79. One potential process is the "huff and puff" method. Steam is injected into a production well, the well is closed for a steam soak period, and then petroleum is produced from the same well. This steam stimulation cycle may be repeated a number of times. A second of the steam injection processes is steam drive (or steam flooding). Steam is injected continuously into injection wells, causing steam, hot water, and petroleum to move laterally to production wells where the petroleum and water are recovered. Hot-water flooding can be considered a variation of steam drive in that hot water is injected in lieu of steam. The two steam injection processes may be combined or used successively, with steam stimulation normally preceding steam drive. The major focus of this plan and program, then, is the application of a well-known technology to a major resource of different characteristics.

2. EMPLOYMENT

a. In Situ Combustion Process Research

Reverse combustion research on LERC field sites will require 10 to 20 workers on the site at one time. Most employees commute from Laramie and stay in Vernal motels during site activity. These figures are accurate for tests #2 and #3.

b. Proposed Steam Injection Experiments

Experimental field tests of steam injection will require 10 to 20 employees at one time. It is expected that they, too, will be housed in Vernal. Coordination of steam experiments with reverse combustion experiments will be necessary to keep manpower requirements at a minimum. Manpower requirements for later "commercial" demonstrations will be higher. Accurate projections will be made as soon as enough is known about the technology for such projections to be meaningful.

c. Proposed DOE Tar Sands Program

Manpower for in situ combustion research and steam injection experiments will be similar to the requirements described above. Manpower for modified in situ experiments and for surface processing experiments associated with mining will most likely be considerably higher because of mining requirements. Again, these projections will have to be made at a later time when input can be more meaningful.

3. WATER CONSUMPTION

A water balance has not been determined for a tar sands experimental site. As experiments proceed, water balances will be necessary to determine cumulative and long-term impacts of process development on regional

water use and demand. A "Preliminary Examination of Waste Waters Produced During an In Situ Retorting of Tar Sands" (LERC, 1977) was made. Analysis of the inorganic material by standard methods as well as spark source mass spectroscopy showed ammonia, sulfate, and chloride to be the predominant ions and iron the major trace element. Organic material isolated from the produced water was found to be the major source of contamination and ranged from 16 to 25 grams per liter. Carboxylic acids, particularly acetic, were found to be the most prevalent. Phenols and lactones have also been identified.

D. POST-OPERATIONAL PHASE

1. IN SITU COMBUSTION PHASE AND PROPOSED STEAM INJECTION EXPERIMENTS

Following completion of experiments, equipment will be removed from the location, and all wells and holes will be plugged before the site is abandoned, in a manner required by the State of Utah and acceptable to the land owner. Coring will take place to evaluate the experimental process. Planning will be necessary to determine the method of revegetation which is most compatible with the experimental site as well as the region as technology develops.

2. PROPOSED DOE TAR SANDS PROGRAM

Revegetation descriptions given above apply for steam injection and reverse combustion experiments under this program. In addition, sophisticated reclamation plans will be required for research involving surface or underground mining.

CHAPTER II

DESCRIPTION OF THE EXISTING ENVIRONMENT

A. AIR QUALITY

1. AIR POLLUTANTS TO BE EMITTED

Air pollution emissions from the tar sands research projects come from three primary sources: (1) noncondensables from the in situ combustion flared and released to the atmosphere; (2) gaseous and particulate emissions from vehicle operations; and (3) fugitive dust caused by vehicles and some earth moving. A typical analysis of gas produced in LERC's first field experiment is given in Table II.A.1. The composition of the produced gas differs from the injected natural air in that the oxygen in the natural air has been reacted to form carbon compounds. The produced gas is monitored and released to the atmosphere. The quantity of gas produced will depend primarily upon the air injection rate; further engineering work is needed to determine the actual output from the vent, but total gaseous emissions could be larger than 1,000 SCFM.

2. EXISTING AIR QUALITY LEVELS

a. Historical Trends in Air Quality

Very few air quality measurements have been made in northeastern Utah. The state of Utah does not have its own air quality monitoring network, and the only monitoring which has been done was in association with the recent oil shale development on public lands in Utah and

TABLE II.A.1 Average gas analysis ("Field Test of Reverse Combustion Oil Recovery from a Utah Tar Sand;" Land, Cupps, Marchant, Carlson; LERC, 1976)

Component	Percent
Nitrogen	79.9
Carbon dioxide	9.5
Carbon monoxide	2.6
Oxygen	2.9
Methane	0.6
Hydrogen	0.5

Colorado. The most extensive nearby data source has been collected for the White River Shale Project; the air quality and meteorology monitoring stations are located approximately 40 miles southeast of the Vernal tar sand site. Data have been collected for only two years, and the results of the second year's data collection (1976) are not yet available. The air quality discussion which follows is based primarily on the first year's data (1975), which have been analyzed by VTN Colorado, Inc. (1976). The data were obtained from a network of as many as eight (depending on the quantities being measured) air quality monitoring stations which were uniformly distributed over the 104 km² area. Measurements were made for several different gases and for total suspended particulates using a variety of instrumentation.

The results of the White River Shale Project air quality monitoring are summarized in Table II.A.2. The federal ambient air quality standards are also included for reference (the State of Utah has adopted federal standards).

TABLE II.A.2 Air quality measurements from the 1975 White River Shale Project and comparative global averages (from Junge, 1963) and the Federal Air Quality Standards (AQS); all units are $\mu\text{g}/\text{m}^3$

Component	Annual Geom. Mean	Global Background	AQS
SO ₂	25	0 - 50	80 (annual) 365 (24 hours)
H ₂ S	8.8	3 - 30	None
O ₃	75	0 - 100	160 (1 hour)
NO ₂	14	0 - 6	100
CO	210	10 - 200	10 ⁴ (8 hours) 4 x 10 ⁴ (1 hour)
NMHC*	634	---	160 (3 hours)
TSP	13	65	75 (annual) 260 (24 hours)

*non-methane hydrocarbons; peak morning readings 0600-0900.

The values in the table demonstrate that the air quality is typical of a remote location which is free of any significant anthropogenic sources of pollution. Indeed, all of the measured components were found to be very near the global background. The NMHC three-hour morning standard was frequently exceeded; the standard was established to reduce the formation of photochemical smog in urban areas, and it is not uncommon to exceed the standard in remote locations. None of the other air quality standards were exceeded.

The tar sands research site is also in a remote location, approximately 4 miles upwind (west) of the nearest source of significant pollution (the city of Vernal, Utah). The proximity of the tar sands

site to the White River Shale Project site suggests that the air quality measurements taken there are probably appropriate estimates of the air quality at the tar sands site. Some air quality measurements should be taken on the tar sands site during the research to verify the usefulness of the extensive two-year White River measurements.

b. Frequency Distributions for Criteria Pollutants

No data are available from the tar sands site. Measurements which were taken as part of the White River Shale Project, some 40 miles southeast, indicate that the pollutant concentrations were never above the federal standards and in fact were very often below the detection limits of the instrumentation. The concentration of total suspended particulates was observed to exhibit an annual trend, with the lowest concentrations during winter and the highest concentrations during summer. This can be explained by the combination of higher summer mean winds and winter snow cover (VTN, 1976).

Some air quality measurements should be taken on the tar sands site to estimate the frequency distributions for criteria pollutants.

c. Air Pollution Dispersion Potential

No data are available from the tar sands site. The nearest location which has a historical record of wind measurements is the Vernal FAA Airport. The utility of these measurements is limited, however, since measurements taken in a river valley (airport) would be substantially different from those on nearby higher land (tar sands site). This difference would be most pronounced during drainage wind conditions, which also have very poor dispersion potential. Therefore, it is essential to obtain some on-site measurements of the low-level winds throughout the year.

Extensive measurements have been obtained as part of the White River Shale Project. Twelve monitoring stations were operated during 1975 in and around the site. The shale site is similar in elevation and terrain to the tar sands site and thus some transferability of results should be possible. The conclusions of the first year's data indicated that the surface airflow patterns were complicated by the terrain features. Drainage winds were typical during the nighttime and early morning hours; wind speeds were light, and directions often followed the major hydrographic drainages. Winds during the afternoon were stronger and more nearly unidirectional, since they were more strongly coupled with the upper-level winds.

The nearest location which has a historical record of atmospheric soundings is the Grand Junction, Colorado, FAA Airport; it is located approximately 100 miles southeast of the tar sands site and in the middle of a large river valley surrounded by mesas several thousand feet higher in elevation. Therefore, the applicability of the Grand Junction observations to the mixing heights 100 miles away is limited. Table II.A.3 gives the historical summary of the mean mixing heights and wind speeds for Grand Junction. The greatest mixing heights and wind speeds occur during spring. The worst pollution dispersion potential occurs during the nighttime and morning hours of summer, fall, and winter.

Observations at the White River Shale Project site included vertical soundings of the lower atmosphere on every sixth day. These data plus some smoke plume tracking experiments were used to assess the dispersion potential. Surface-based inversions were commonly observed during the morning hours throughout the year. These inversions usually dissipated by mid-afternoon except during the winter months, when an elevated

TABLE II.A.3 Mean mixing heights and wind speeds, Grand Junction, Colorado (from Holzworth, 1972)

	Mixing Height in meters (feet)				Wind Speed in m/s (mph)			
	Morning		Afternoon		Morning		Afternoon	
Winter	329	(1,079)	1,161	(3,806)	3.4	(7.6)	3.4	(7.6)
Spring	628	(2,060)	3,168	(10,387)	5.4	(12.1)	6.6	(14.8)
Summer	307	(1,007)	3,942	(12,926)	4.7	(10.5)	6.1	(13.6)
Autumn	273	(896)	2,134	(6,998)	3.9	(8.7)	4.6	(10.3)
Annual	384	(1,260)	2,602	(8,530)	4.3	(9.6)	5.2	(11.6)

inversion could still be detected. During the other seasons, neutral stability was usually observed during afternoons, so that vertical mixing would be rapid. In summary, the worst surface pollution dispersion potential occurred during the nighttime and early morning hours of winter.

Some measurements of the mixing level heights over the tar sands site should be obtained. These data together with measurements of the low-level winds could be used to establish the site-specific dispersion potential.

d. Basic Meteorological Data

No historical record is available from the tar sands site. There are several climatological stations (which are part of the national network) located nearby in Vernal, Fort Duchesne, Roosevelt and Neola (NOAA, 1976). All of these stations record temperature and precipitation; Vernal also records surface winds and Fort Duchesne records the summer season pan evaporation. Data are also available from the White River

Shale Project for 1976; some of the twelve monitoring stations measured temperature, humidity, pressure, surface winds, and radiation flux.

Climate and Monthly Summaries of Temperature and Precipitation

The climate of the region is typical of a mid-latitude, high-altitude (5,000 ft MSL) continental location. Large mountain ranges surround the region and are very important in influencing the local weather: in winter, all but the strongest cold air masses are blocked by the mountains, so that little precipitation occurs during the winter and winter temperatures are usually quite mild; in summer, the high altitude, dry air, and sloping terrain provide large rates of daytime heating and nighttime cooling, so that the diurnal temperature range is quite large (as much as 30°F); moist maritime low-level air is usually blocked by the mountains during summer, so that humidities are quite low; summertime precipitation is usually due to infrequent afternoon thunderstorms. Basic annual precipitation is only about 8 inches and is distributed approximately uniformly throughout the year. Table II.A.4 is an annual summary of climatological data for Vernal, the station nearest the tar sands site. Normals are based on the time period 1941 to 1970. Temperature extremes during 1976 included a high temperature of 99°F on July 10 and a low of -12°F on January 2. The 1976 frost-free season extended from June 14 to September 29, for a total of 107 days.

The region receives .01 inch precipitation or more on only 60-90 days per year. Regional low-elevation snowfall is approximately 15 inches per year, with the greatest amount (6 inches) occurring during January. Thunderstorms occur over the region on approximately 40 days per year. Total annual pan evaporation is approximately 50 inches, or about six times larger than the total precipitation (Baldwin, 1973).

TABLE II.A.4 Annual climatological summary for Vernal, Utah (NOAA, 1976); values are normals for 1941-1970

	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave. Temp. (°F)	45	16	23	34	46	55	62	70	68	59	47	33	21
Precip. (in.)	7.82	.54	.42	.52	.73	.62	.96	.45	.76	.66	.90	.55	.71

Wind Roses

A historical record of several years of wind data is available for the Vernal FAA Airport. These data will be analyzed for the tar sands project reports. Wind rose analysis has been performed for the White River Shale Project for 1975 data. The results of that analysis are presented in Figure 3 according to season. All four seasons have dominant southeast winds at 6 to 12 mph, with a secondary westerly tendency. Calm periods (wind less than 3 mph) were observed 16 percent of the time during winter, 8 percent during spring and summer, and 4 percent during fall. This station is located on a small, gentle ridge about one mile south and 200 feet above the White River (which runs approximately from east to west); higher terrain is located several miles south. These wind rose patterns suggest that light drainage winds (southeast at 6 to 12 mph) were quite common. Lighter wind speeds were distributed approximately evenly and stronger winds show a preference for the southwest quadrant. If the general tendency for light drainage winds holds true for the tar sands site, then light westerly winds would be favored. The combination of calm or light west winds and persistent low-level

Figure 3. Relative frequency distribution (%) of surface wind speed and direction at Station A-6 in all four seasons (from VTN, 1976). Circled numbers are wind speed readings in mph; multiply by 0.44 to get speeds in m/s.

inversions suggests that winter is the worst season for pollution dispersion. Light west winds would carry surface-produced pollution toward the town of Vernal, Utah, some four miles away.

The strong dependence of the surface winds upon the topographic features emphasizes the need for measurements to be taken at the tar sands site.

B. WATER QUALITY

1. PHYSIOGRAPHY

The research site is located in the Uinta Basin of northeastern Utah, about 4 miles west of Vernal (Figure 4). The basin is bounded on the north by the Wasatch Range. To the east the land rises to low mountains and plateaus. The East and West Tavaputs Plateaus bound the southern portion of the basin.

Much of the basin consists of a highly dissected land surface with deep, steep-sided canyons. Elevations vary from 13,528 feet atop Kings Peak to about 4,700 feet where the Green River enters Desolation Canyon at the southern end of the basin. The plateaus adjacent to Desolation Canyon rise to over 9,000 feet.

Vernal is located in Ashley Valley at an elevation of 5,330 feet. This valley lies at the northern end of Uinta Basin. It is a relatively flat area of roughly 70 square miles that is used for irrigated agriculture. Asphalt Ridge rises to over 6,600 feet on the southwestern side of the valley.

The research area lies on a broad ridge that forms a saddle between Asphalt Ridge to the southeast and Little Mountain to the northwest (Figure 5). Elevations in the research area range from 5,820 to 6,040 feet. The existing research site lies on relatively even and flat ranges from 5,950 to 5,970 feet. The land slope is 3 percent from west to east across the research site (LERC, 1974).

2. STRATIGRAPHY

The tar sands research site is located west of Vernal, in the Northwest Asphalt Ridge tar sands deposit within the Uinta Basin. The oil-saturated zones of tar sands are found in the Mesa Verde and

VERNAL

P. O. Box 836
Vernal, UT 84078
Phone: Extension 347
Comm: FTS-588-5500
and ask for 789-5234

FIGURE 4. TAR SAND RESEARCH AREA NEAR VERNAL, UTAH

FIGURE 5. CANALS AND EPHEMERAL STREAMS NEAR THE TAR SAND RESEARCH AREA

Duchesne River geologic formations (Figure 6). Two sandstone layers in the Mesa Verde Formation contain the oil: the Asphalt Ridge sandstone layer, which is at the base of the Mesa Verde Formation and is confined by shale deposits above and below, and the Rim Rock sandstone layer, which is the richest tar sands in the area and is found at the top of the Mesa Verde Formation. The Rim Rock layer is also confined by shale deposits. The Duchesne River Formation is mainly a conglomerate with boulders up to 6 inches in diameter and has lower and more irregular saturation of oil than zones of the Mesa Verde Formation. The field tests for in situ recovery of tar sands are being conducted on the Rim Rock sandstone, which is a fine- to medium-grained and loosely consolidated to unconsolidated sandstone. Figure 6 shows the approximate location of the test site in relation to the outcrop area which occurs about 1/4 mile to the north and east of the test site. The test zone averages about 300 feet below the surface and is approximately 10 feet thick. The dip of the formation beds in the area are generally between 10° and 25° to the south and west and the strike is generally northwest-southeast (LERC, 1974).

3. GROUNDWATER

In the Uinta Basin, a known and probable source of groundwater has been identified for the Ashley Creek area by the Utah Division of Water Resources. This area is known as the South Flank Uintas groundwater basin. The recharge for this basin is from the Uinta Mountains where surface water and local precipitation are available to recharge the bedrock aquifers. The Duchesne River Formation in this area yields fresh water to wells for domestic and municipal supply. Fresh water has been found at considerable depths in the Weber Sandstone and the Green River Formation on the north flank of the basin, and these formations

FIGURE 6. IDEALIZED GEOLOGIC CROSS SECTION THROUGH EXPERIMENTAL SITE

may be recharged to a great extent by interformational leakage. Other formations such as the Mancos Shale, Navajo, and Entrada contain fresh or slightly saline water along the north flank of the Uinta Basin. A number of observation wells are monitored in and around Vernal by the State of Utah (Jeppson et al., 1968). Some of the observation data from a few of these wells are reported in "Ground-Water Levels in the United States, Northwestern States" as a USGS Water-Supply Paper approximately every five years. The closest well recorded to the site in the above report is in Section 23, T 4 S, R 21 E, and is located in the alluvium of the Duchesne River Formation.

The USGS has identified several flowing wells and springs approximately 2 to 2.5 miles north in what is known as Coal Mine Basin (Vernal NW and NE Quadrangle 7.5 minute series topographic maps). No further information was found on these flowing wells and springs.

a. In Situ Combustion Research

At the tar sands research site, it has been indicated that no ground water exists for depths up to 900 feet. A large number of core holes have been drilled which at least penetrate the tar sands in a 320-acre area in and around the site, and no indication of any appreciable groundwater has been found (LERC, 1974). The absence of groundwater in and around the research area does not seem typical since the surrounding area does not indicate this pattern. One possible explanation for the absence of groundwater around the research site could be the fact that the surface water divide is nearby and the outcrop area of the formations near the surface are some 1/4 mile away in an area of low precipitation and little surface drainage. The research site itself is most likely part of the upper recharge area for the surrounding

formations. Although groundwaters have not been found at depths up to 900 feet, groundwater has been found in the area surrounding the research site. It would seem reasonable that groundwaters would be found in formations above and below the tar sand beds in other tar sands areas which are considered for future development. No drilling has been done specifically to determine if groundwaters do or do not actually exist in and around the research site. Many times during core drilling a small amount of water is encountered but seems insignificant because it is not usable for domestic or irrigation purposes. A small drilling program should be set up to verify the actual non-existence of water. A set of logs should be obtained on all holes drilled and well completion should seal the different formations. This drilling program could serve a dual purpose since the wells could also be used as monitoring wells to see if the produced waters generated from in situ retorting move down gradient through the formation and what the changes in water quality are as a result of movement. It would be expected that the produced waters would move in the same direction as the dip of the formations. The results of a small monitoring program on the research site would be of great advantage in future development in that some of the worst conditions would be revealed since groundwaters would be encountered in commercial scale operations and would tend to dilute the produced waters.

b. Future Tar Sands Projects

Groundwaters which would exist in the alluvium, colluvium, and fractured uppermost layers of bedrock and in deeper confined aquifers in areas of future tar sand development should not be forgotten even though they do not exist at the DOE tar sands research site. In general,

the shallow alluvium, colluvium, and fractured uppermost layers of bed-rock are unconfined or semi-confined aquifers that are interconnected with local surface streambeds. The flow of water will either be toward or away from the streambed. Studies should be made on streams in the area of future tar sands development to determine if the streams are being fed by the groundwater and when they are feeding the groundwater system. Only small amounts of this shallow groundwater will usually leak to lower aquifers through the confining beds (aquitards) or vice versa unless disrupted by faults or large cracks which then create spring or seepage-type areas.

These shallow aquifers play an important immediate role in relation to the nearby surface streams and must be evaluated for possible future impacts due to disruption of lower aquifers interconnecting with these shallow aquifers due to true or modified in situ retorting of tar sands or surface mining of the material. At present, no information exists on the shallow aquifer systems surrounding the tar sands research site in the study area.

The deeper aquifers are usually confined and are separated by zones of less permeable aquitards. In the preoperational studies on new developments of tar sands, it is important that a drilling program to determine the different aquifers above and below the oil-saturated layers (tar sands) be performed. A set of logs on each hole and a detailed completion report on what aquifers are being monitored must be required. Intercommunication of aquifers due to a poor well completion or noncompletion should not be allowed in a preoperational study. Aquifer parameters and any intercommunication between aquifers must be determined in the preoperational phase. The in situ retorting process may cause fractures in the aquitards above and below the oil-saturated

layers resulting in intercommunication which can only be detected with a monitoring program which samples water levels and water quality of each of the different aquifers above and below the oil-saturated layers before and during the actual operation phase.

A future research site should be picked where both the shallow and deep aquifer characteristics can be studied in more detail during in situ retorting.

4. SURFACE WATER HYDROLOGY

The Green River, the largest stream in the area, is highly regulated upstream by Flaming Gorge Reservoir. This stream originates in Wyoming and flows through the Uinta Basin about 12 miles southeast of the research area (Figure 4). Numerous tributaries originating in the mountains bounding the basin contribute significantly to the Green River. The average annual runoff of the Green River is 3,304,000 acre-feet near Jensen, Utah, and 4,180,000 acre-feet below the inflow points of major Uinta Basin tributaries (Jeppson et al., 1968). The major tributaries are the Duchesne River, Uinta River, White River, Ashley Creek, and Brush Creek (Figure 4).

Most of the perennial stream runoff is derived from mountain snowmelt that occurs in the spring and early summer. Runoff for the remainder of the year is primarily derived from groundwater effluent, mostly from the alluvial aquifers associated with the streams. These aquifers are recharged by snowmelt runoff and irrigation.

Ashley Creek, 4 miles northeast of the research area, is the nearest perennial stream. It is diverted at the head of Ashley Valley for irrigation. It does not become perennial again until 1.5 miles east of Vernal, where it is recharged from irrigation return flow. The

amount of consumptive use of the stream is indicated by the average annual flow of 89,050 acre-feet above the valley and 39,460 acre-feet at the mouth (Jeppson et al., 1968).

There are numerous streams originating in the lower elevations that are ephemeral or intermittent (Figure 5), flowing only in response to rainstorms or snowmelt. There are several canals in Ashley Valley which transport irrigation water and in some instances serve as collectors of ephemeral stream runoff. The Highland Canal, about 1.5 miles east-northeast of the research area, carried 8,612 acre-feet of water during the 1973 irrigation season. The Ashley Upper Canal, about 0.5 miles east of the Highland Canal, carried 24,240 acre-feet during that period (LERC, 1974).

The southern approximately two-thirds of the land at the research area drains into Twelvemile Wash, an ephemeral or intermittent stream that is tributary to the Green River about 13 miles to the south. The northern portion of the research area drains into ephemeral streams that drain into Highland Canal. Several of these streams head on the research area, but none of them are within the present research site.

Steinaker Reservoir, at the head of Ashley Valley, is the only major reservoir in the area. There are several stockwater reservoirs in the vicinity, but none are located within the research area.

During the summer months warm moist air from the Gulf of Mexico flows into Utah. Most of the resulting precipitation is delivered in intense storms. The principal area of heavy activity is along the southeastern slopes of the Uinta Range which includes the research area. Summer thunderstorms produce a major portion of the annual precipitation, with a secondary maximum associated with fall low-pressure systems (Jeppson et al., 1968).

Runoff events that result from the intense storms in the area have not been well quantified. Soil erosion and channel head cutting have resulted from runoff events in the basin..

5. SURFACE WATER QUALITY

No water quality data are presently available for Ashley Creek and the two irrigation canals which are part of the Ashley Creek distribution system.

However, a publication by the Upper Colorado Region State-Federal Interagency Group (1971) indicated that TDS levels in the surface waters in proximity to Vernal are generally in the range of 250-1000 mg/l with sodium adsorption ratio (SAR) values of less than 3. Hardness is generally greater than 180 mg/l as CaCO_3 .

Jeppson et al. (1968) indicate the average salinity of the Green River at Jensen, about 12 miles southeast of Vernal, is 316 mg/l. Typical water quality at this location is indicated in Table II.B.1.

6. GROUNDWATER QUALITY

There are no groundwater quality data available near the site. However, the publication by the Upper Colorado Region State-Federal Interagency Group (1971) does indicate groundwater in the near vicinity of Vernal has SAR values in the range of 3-5.

TABLE II.B.1

Typical water quality data for Green River
near Jensen, Utah (all concentrations are in mg/l).

Parameter	Discharge Weighted Average	Range
Na	42	11 - 73
HCO ₃	160	104 - 200
CO ₃	0	0
SO ₄	129	50 - 264
Cl	17	5.2 - 35
TDS	356	172 - 555
SAR	1.2	0.4 - 2.1
pH	7.6	7.3 - 8.2

Source: USGS, Water Resources Data for Utah, Water Year 1965, Part 2.

C. BIOLOGICAL

1. AQUATIC

a. Introduction

The in situ tar sand experimental site operated by DOE near Vernal, Utah, will not adversely affect aquatic biota which inhabit the lower Green River. Because of the small size of the project, containment measures initiated, and the relatively long distance to any perennial body of water, no adverse impacts upon this aquatic habitat are anticipated. Expanded tar sands projects in the future will have greater potential for damaging aquatic habitats and will require careful consideration of rare and endangered fish species, groundwater escapement of toxic substances, and wastewater treatment or disposal.

The experimental site is arid and has no aquatic habitats within its boundaries.

b. Vernal Site

Pollutants from the research project could enter the Green River approximately 13 miles southeast of the site through a series of dry washes. No perennial water source exists in the drainage area from the experimental site to the Green River. Ashley Creek, a perennial stream habitually dewatered during the irrigation season, is located 3.5 miles northeast of the study site. Ashley Creek presently is not considered to be a viable fishery in the vicinity of the study site because of the severe dewatering (Robinson, U.S. Fish and Wildlife Service, Personal Communication, 1977). Although this creek and the experimental site are in different drainage basins leading to the Green River, the close proximity of the site to the drainage divide could conceivably result in pollutants entering Ashley Creek and ultimately the Green River from this source. This possibility is currently considered to be highly unlikely.

The Green River below Dinosaur National Monument is a large, turbid, low-gradient stream containing warmwater fish species. It is a final stronghold of the Colorado squawfish (Ptychocheilus lucius) and Humpback chub (Gila cypha), both of which are listed as endangered by the U.S. Department of the Interior. The Humpback sucker (Xyrauchen texanus) and Bonytail (Gila elegans) also inhabit this area and are listed as declining (depleted, continuing to decline, requiring management to halt this decline) by the State of Utah.

The primary sport fishery in the Green River below Dinosaur National Monument is for Channel catfish (Ictalurus punctatus). Walleye (Stizostedion vitreum) are apparently present in low numbers, and Small-mouth bass (Micropterus dolomieu) are becoming established in the vicinity of the Ouray Indian Reservation (Robinson, U.S. Bureau of Sport Fisheries and Wildlife, Personal Communication, 1977). No other game fish inhabit this area of the Green River in numbers sufficient to consider.

Important non-game species include Carp (Cyprinus carpio), Redside shiner (Richardsonius balteatus), Bluehead sucker (Catostomus discobolus), and Flannelmouth sucker (Catostomus latipinnis).

2. VEGETATION

a. Environment

The tar sand deposits pertinent to LERC's research endeavors near Vernal, Utah, are located under vegetation types characteristic of those found within the Great Basin, and specifically those found within the Uinta Basin, a depression of the Green River Formation (Figure 7).

Shrubland, juniper stands, and riparian vegetation typify the area around the existing research site. The shrub communities are typical of those described by Harrington (1964) for his semi-desert area and Nelson's (1897) cold desert shrublands. Juniper stands occupy the higher plateau areas and can be found on the slopes of ridges and lower drainages of perennial or intermittent streams. Riparian communities occupy narrow stretches of lowlands along perennial streams or as induced communities from irrigation projects.

This vegetation pattern is an end result of the climate of the region. Less than 10 inches of moisture falls annual, most in the form of snow during the winter months. Moisture falling during the growing season results from localized thunderstorms. The moisture most often leaves as surface runoff and is not available to resupply soil moisture for plant growth. Consequently, snowmelt and spring snowstorms and rains during March and April are most important in sustaining the existing vegetation by providing both surface and deep soil moisture reserves from year to year.

b. Vegetation Types and Distribution

Four broad vegetation types exist in the area surrounding the tar sands research site. These include Big sagebrush (Artemisia tridentata),

FIGURE 7- GREEN RIVER FORMATION.

Black greasewood (Sarcobatus vermiculatus), Utah juniper (Juniperus utahensis), and riparian.

Riparian. Riparian communities lie to the north and east of the research site and are represented by croplands under irrigation and native plant associations along the Green River and other perennial streams. Riparian communities have not been mapped since they are not part of the research site and only become significant in the event of an expanded program.

Black greasewood. Black greasewood is a salt-tolerant shrub and occupies deep soils within lowlands, flats, and along the bottoms of deep draws and canyons where saline conditions occur. No associations of greasewood are located on or in close proximity to the research site. It becomes a dominant type to the south of the study area. This type has not been mapped since it is not part of the research site and only becomes significant in the event of an expanded program.

Utah juniper. Juniper stands are prevalent near the study area, occupying portions of Asphalt Ridge to the west and along the eastern slope of the upland on which the research site is located. This type has not been mapped since it is not part of the research site. Because of its close proximity, mapping should take place in the event of an expanded program.

Big sagebrush. The entire 10-acre research site is located within Big sagebrush vegetation type and the stand surrounding the site reveals that the shrub is homogeneous. The plants are approximately 2 feet in height, and new seedlings are not evident, indicating a closed sagebrush community. This sagebrush type gives way to the juniper stands along

the upland on which the research site is located, and then continues to the north to where irrigation takes place. To the west and east it again gives way to the juniper type. It continues to the south as the dominant vegetation type. No mapping of the distribution of vegetation of surrounding or site-specified land for documentary purposes has taken place. Any expanded program should entail doing so.

c. Species Description

Dominant species of the Big sagebrush vegetation type surrounding and including the tar sands research site as reported by BLM officials (LERC, 1974) include:

<u>Common Name</u>	<u>Scientific Name</u>
Shrubs:	
Winterfat	<i>Erotia lanata</i>
Black sagebrush	<i>Artemisia nova</i>
Bud sagebrush	<i>Artemisia spinescens</i>
Big sagebrush	<i>Artemisia tridentata</i>
Shadscale saltbush	<i>Atriplex confertifolia</i>
Rabbitbrush	<i>Chrysothamnus</i> spp.
Prickly pear cactus	<i>Opuntia</i> spp.
Grasses:	
Western wheatgrass	<i>Agropyron smithii</i>
Bluebunch wheatgrass	<i>Agropyron spicatum</i>
Cheatgrass brome	<i>Bromus tectorum</i>
Galleta hiliaria	<i>Hilaria jamesii</i>
Prairie junegrass	<i>Koeleria cristata</i>
Indian ricegrass	<i>Oryzopsis hymenoides</i>
Bottlebrush squirreltail	<i>Sitanion hystrix</i>
Needle-and-thread	<i>Stipa comata</i>
Trees:	
Utah juniper	<i>Juniperus utahensis</i>
Forbs:	
Common Russian thistle	<i>Salsola kali</i>
Scarlet globemallow	<i>Sphaeralcea coccinea</i>

A complete species list and collection for the research site has not been carried out at the present time. Any expanded program should

include collecting plant specimens of all species within the existing research site and surrounding habitats for documentary and planning purposes.

d. Rare and Endangered Species

Comparison of the 1974 species list above with "Threatened or Endangered Fauna or Flora" (USDI, Fish and Wildlife Service, 1975) indicates no rare or endangered plant species occur within the native range of the tar sands research site. The plants listed are characteristic of the Big sagebrush vegetation type. Plant collections normally are updated as research continues on specific research sites. There is a possibility, because of their rare occurrence and chance of being overlooked, that rare and endangered species may be found. If this is so, verification and notification will be carried out.

e. Past and Present Management

The semi-arid Big sagebrush vegetation types of the Uinta Basin and areas surrounding Vernal have been and are presently being utilized for grazing of livestock and wildlife. The tar sands research site is located within a 320-acre tract under private ownership which is unfenced. Consequently, cattle, sheep, and horses utilizing state and public grazing lands may occasionally stray around the fenced research site. No grazing occurs within the existing study area by large herbivores. Small mammals are not excluded.

f. Natural Succession

The Big sagebrush vegetation type surrounding the study area represents a climax condition for the existing range site and climatic

conditions of the region. The density of sagebrush plants and associated species of grasses and forbs may vary depending on range conditions resulting from grazing pressure, but sagebrush will remain dominant without man's manipulation.

The semi-arid broad, flat ridge with well-drained sandy loam surface soils surrounding the research site is conducive to the propagation of Big sagebrush. The root system of this plant is capable of collecting deep soil moisture by an extended tap root. In addition, the plant has a well-developed lateral root system for collecting moisture near the surface of the soil, enabling it to utilize rainfall during the localized summer thunderstorms.

The scattered juniper stands, on the other hand, have an extended root system near the surface of the soil enabling it to outcompete sagebrush on shallow soils along sandstone outcrops and eroded slopes at higher elevations. It has no tap root to collect deep soil moisture.

Greasewood, although having a root system similar to sagebrush, depends on an extended tap root for most of its moisture supply. It outcompetes sagebrush on deep saline soils in that it is salt-tolerant compared to Big sagebrush.

Perennial forbs and grasses are associated plants and utilize the available surface moisture during spring months to fulfill their growth cycle. The extent of the associated flora depends on the density of the dominant shrubs and juniper, and the frequency and extent of summer storms. Annual grass and forb species are prevalent in overgrazed and disturbed areas during early spring when surface moisture is available. During wet summers this flora may flourish over an extended period of time (VTN, 1975).

3. TERRESTRIAL FAUNA

a. Introduction

The LERC experimental site lies about four miles west of Vernal in northeast Utah. This area is part of the northern desert shrub grazing region, as is most of Utah, according to Stoddart and Smith (1955). This region is dominated by Sagebrush (Artemisia spp.) and other xeric shrubs of the Compositae and Chenopodiaceae families (Fautin, 1946; Stoddart and Smith, 1955; Odum, 1971). The 10-acre site is totally within a Big sagebrush (Artemisia tridentata) type plant community, and this community will be the major wildlife habitat type discussed.

b. Birds

The avifauna that may occur with habitat types similar to that surrounding the site are listed in Appendix A. This list was compiled from inventories made in the northern desert shrub zone, including inventories of historic importance, such as Cary's observations in 1917, and recent works such as VTN's observation in 1975. These inventories are of a regional nature and do not indicate the presence or absence of any species upon the site, only their possible presence. To determine the avifauna using the proposed development area, on-site inventories would be necessary. These inventories should be made during each season to determine changes in species composition. Disturbances within a sagebrush habitat would disrupt not only birds that nest in this type of habitat, but also those that nest in other habitats such as the nearby juniper brakes and forage or hunt in the sagebrush habitat.

c. Mammals

A list of mammals that may occur in the northern desert shrub region is given in Appendix B. This list was compiled through a review of previous inventories of the region. Inventories of historic importance such as Cary's observations in 1917 were included, along with recent studies by VTN. The inventories used were made in areas of habitat types similar to the proposed experimental site, but to determine actual species composition of the area site-specific studies are needed. The ecological importance of the area to game species is not known at this time, but only an occasional hunter uses the area and less than 12 hunter days per year are spent in pursuit of game species (Bureau of Mines, 1974).

d. Amphibians and Reptiles

Amphibians and reptiles play an important role in the environment, acting both as predator and prey species. The number of amphibians using the experimental site would be insignificant due to the lack of aquatic habitats in the area. Reptiles that were found to be present in sagebrush-type habitats on Utah oil-shale tracts a and b by VTN (1975) and that might be found on the site are listed below:

Eastern fence lizard	(<u>Sceloporus undulatus</u>)
Sagebrush lizard	(<u>Sceloporus graciosus</u>)
Short-horned lizard	(<u>Phrynosoma douglassi</u>)
Side-blotched lizard	(<u>Uta stansburiana</u>)
Western whiptail	(<u>Cnemidophorus tigris</u>)
Striped whipsnake	(<u>Masticophis taeniatus</u>)
Gopher snake	(<u>Pitnophis melanoleucus</u>)
Western terrestrial garter snake	(<u>Thamnophis elegans</u>)
Western rattlesnake	(<u>Crotalus viridis</u>)

The status of amphibians and reptiles on the site could only be determined through site-specific studies.

e. Invertebrates

Invertebrates are important to the existing environment as primary consumers, secondary consumers, and as a food source for other vertebrate fauna. Investigations of the status of invertebrates within the area and their relations to the existing environment might prove valuable in determining relationships with plant growth for revegetation practices and food chain kinetics if large-scale operations become a reality. At the present scale of research, with limited acreages of less than 10 acres per site, a survey of invertebrates is not deemed necessary.

f. Rare and Endangered Species

The only rare or endangered species that might appear in the region and in a sagebrush habitat type are the American Peregrine falcon, the Black-footed ferret and the Utah prairie dog. All three of these animals are classified as endangered by the U.S. Department of the Interior, Fish and Wildlife Service. The status of the Peregrine falcon and the Utah prairie dog within the region are not known at this time. Utah is on the extreme western portion of the Black-footed ferret's range, and they never existed in great numbers in the state. There have been three unconfirmed sightings in the eastern portion of the state in recent years, however; two were in the Uintah Basin and one was near Green River, Utah (Utah Division of Wildlife Resources, 1976).

The Utah Division of Wildlife Resources lists no animals that would be found in a sagebrush habitat as endangered. They do list the Bobcat, which is a common visitor and, if conditions are right, a resident of the sagebrush habitat, as declining. The Bobcat is not protected at this time but may be in the future.

Studies should be conducted to determine if any rare or endangered species use the area. These studies should run for one full year to determine if migrant species use the area in any particular season.

D. AESTHETIC, RECREATIONAL, AND CULTURAL

1. KNOWN CULTURAL RESOURCES

No archaeological or historic sites are known from the immediate vicinity of the proposed experiment station. The site itself was surveyed for cultural sites by Mr. Curt Tucker of the Vernal District of the Bureau of Land Management, who reported an absence of sites. The Cultural resource files at the District Office of the BLM in Vernal and at the Office of the State Archaeologist in Salt Lake show no sites within several miles of the property. Very little of the surrounding area has been surveyed for sites, however.

2. POTENTIAL CULTURAL RESOURCES

Within the immediate experimental area no sites were found after a complete inventory. The Vernal area in general, however, is estimated to be one of moderate to moderately high archaeological site density by Lar Mar W. Lindsay, the Assistant State Archaeologist. Known site types within the area include campsites, quarries, pictographs, petroglyphs, ceramic sites, granaries, and Fremont house structures. Kill sites for game animals and recent sites relating to the Ute Indians occupation potentially exist. Because of the lack of water near the experiment site the probability of sites in the immediate locality is low.

3. AESTHETIC VALUES

Lying close to Utah Highway 121, the site can be seen, but it is not in full view of the roadway. The site has less than 20 feet of relief and is not impressive topographically. A 40-acre tract near the experiment area has been stripped for gravel by local construction firms.

A Utah Power and Light transmission line also passes adjacent to the site. No perennial drainages exist within several miles of the site. The site itself would not block a view of surrounding terrain as seen from Highway 121.

Vegetation on site consists of low desert shrubs and grasses. The site is in no way distinctive from an aesthetic viewpoint, and is already partially altered.

4. RECREATIONAL OPPORTUNITIES

Recreational opportunities are greatly restricted at the site. The land is privately owned so access is determined by the landowner. Big game animals are rare, with mule deer being the only occasional transient. Small game is present but the Draft EIS for the site estimates that less than 12 hunter days per year are spent there.

No water is on or near the site so waterfowl hunting, boating, fishing, and swimming are not possible. The land ownership status could limit access for motorcycling or 4-wheeling and hiking.

E. SOCIOECONOMIC ENVIRONMENT

1. POPULATION CHARACTERISTICS AND TRENDS

Utah is not a heavily populated state. Averaging 14.1 people per square mile it had a population of 1,065,000 in 1970. This represents over a 100 percent increase from a 1930 population of 509,000. Uintah County averages 2.83 people per square mile and had a 1970 population of 12,684. Uintah County has not experienced population growth comparable to the state until recently. The 1930 population for Uintah County was only 9,035. Therefore, the county has only grown 40 percent between 1930 and 1970, while the state population increased by over 100 percent during the same period (see Table II.E.1).

Uintah County did experience substantial population growth between 1970 and 1973 (19.8 percent). This rate of growth was more than double that of the state as a whole. Assuming steady growth during that period this would be equivalent to 6.6 percent growth in population per year for the county as compared to a growth rate of 3.1 percent per year for the state during the same period of time.

Vernal, the population center for Uintah County, had a 1974 population of 5,000. This represents only 32.89 percent of the total county population. Table II.E.2 shows the percentages of urban and rural farm and nonfarm dwellers in Uintah County and the State of Utah for 1960 and 1970.

The percentage of urban dwellers in Uintah County rose slightly between 1960 and 1970 (from 31.6 percent to 32.7 percent). More important, however, was the reduction in rural farm dwellers from 21.9 percent in 1960 to only 16.1 percent in 1970. The area experiencing the most growth in this decade

TABLE II.E.1. Population changes for Uintah County and Utah since 1930

	1930	Change in % to	1940	Change in % to	1950	Change in % to	1960	Change in % to	1970	Change in % to	1973
Uintah Co.	9,035	9.6	9,898	4.1	10,300	12.5	11,582	9.5	12,684	19.8	15,195
Utah	509,000	8.5	552,000	26.1	696,000	29.3	900,000	18.3	1,063,000	9.2	1,162,980

Sources: Utah Foundation, Statistical Review of Government, 1975 edition, Salt Lake City, Utah; Western Environmental Associates, Inc., 1975a; University of Wyoming, Department of Sociology calculations.

TABLE II.E.2 Percent of total county population living in rural farm, rural nonfarm, and urban areas, 1960 and 1970

	Rural Farm		Rural Nonfarm		Urban	
	1960	1970	1960	1970	1960	1970
Uintah Co.	21.9	16.1	46.5	51.2	31.6	32.7
Utah	7.0	2.4	18.1	17.0	74.9	80.6

Sources: U.S. Department of Commerce, Bureau of the Census, 1960 and 1970 Census of Population; Western Environmental Associates, Inc., 1975a.

was rural nonfarm dwellers (46.5 percent in 1960, 51.2 percent in 1970). This increase shows a reversal from the pattern observed in the state as a whole among the rural nonfarm dwellers. Characteristic of this trend for the state is the increase in the percentage of people living in urban areas (74.9 percent for 1960, as compared to 80.6 percent in 1970).

This trend for the rural nonfarm sector of Uintah County to grow more rapidly in relation to the other sectors is most probably accounted for by the availability of city services (i.e., water) outside the city limits. Water from the Vernal city system is available in the county areas surrounding the city. Also, zoning laws and building codes are less stringent in the county as compared to the city, and land is less expensive outside the city limits.

a. Early History

The now extinct basketmaker people were the first on record to inhabit what is now Uintah County 1,500 years ago. They were followed by the Indians. Spanish explorers were believed to be the first white

men to pass through the Uintah Basin in 1776. A Mormon scouting party went through the area in 1861. The Uintah Basin was first settled by livestock men and miners in the late 1870's (Vernal Area Chamber of Commerce). Although Mormon colonization efforts were directed toward southern Utah initially, after the formation of the Uintah-Ouray Indian Reservation (part of which is in Uintah County) Mormons began to settle the arable land surrounding the reservation. Vernal was established as "Ashley Fork Center" in 1878 and was soon joined by half a dozen other farming and ranching communities in the area (Logan et al., 1976:60).

The principal means of livelihood were farming, livestock, lumbering, and mining from the time of the first settlements until oil was discovered in Uintah Basin in 1948. The Ashley and Red Wash oil fields, both in Uintah County, are now the major producers of oil in Utah (Vernal Area Chamber of Commerce). Therefore, since 1948 the major portion of the population growth can be attributed to the expanding oil and mineral industries. Not only has this been the case in the past, but it is expected to continue into the future. Much of the oil shale reserves of the United States are located in or near the area; therefore, continued growth related to oil is probable.

b. Age Distribution

Table III.E.3 indicates that Uintah County has a higher percentage of persons under the age of 18 than both the state as a whole and the United States. Reflecting this higher proportion of young persons is the median age of 22.4 for Uintah County, 23.1 for Utah, and 28.1 for the United States. The lower median age could represent migration of young workers to the oil and resource recovery industries in the county.

TABLE II.E.3 Age dependency ratio for Uintah County, Utah, and the United States, 1970

	Uintah County	Utah	United States
Persons under 18			
Number	5,637	423,850	69,644,081
Percent	44.4	40.0	34.3
Persons over 65			
Number	877	77,561	20,065,502
Percent	6.9	7.3	9.9
Total			
Number	6,514	501,411	89,709,583
Percent	51.4	47.3	44.1
Median Age	22.4	23.1	28.1

Sources: U.S. Department of Commerce, Bureau of the Census, 1970
Census of Population; Logan et al., 1976.

c. Sex Distribution

Males outnumber females in Uintah County and have since 1950. Table II.E.4 shows the number and percentage of males to females from 1950 to 1970 for both Uintah County and Utah. The trend for Uintah County since 1950 does indicate regression toward the national norm where women represent approximately 51 percent of the population of the United States. The state of Utah has been undergoing this gradual transition since 1950, when men represented 50.5 percent of the population, and in 1970 males represented only 49.9 percent of the population

d. Ethnic Groups

The largest single minority group within the study area is Indian. This is because a portion of the Uintah and Ouray Indian Reservation is located in the southwestern part of the county. Indians represented 10.54

TABLE II.E.4 Population distribution by sex for Uintah County and Utah, 1950-1970

	1950		1960		1970	
	Male	Female	Male	Female	Male	Female
Uintah Co.						
Number	5,337	4,963	4,984	5,598	6,425	6,259
Percent	51.8	48.2	51.7	48.3	50.7	49.3
Utah						
Number	347,636	341,226	444,924	445,703	523,265	526,008
Percent	50.5	49.5	50.0	50.0	49.9	50.1

Sources: Kunz, 1969; Logan et al, 1976; U.S. Department of Commerce, Bureau of the Census, 1950, 1960, and 1970 Census of Population; University of Wyoming, Department of Sociology calculations.

percent of the county's population in 1970, whereas they represented only 1.1 percent of the state's population (See Table II.E.5). The white majority group accounts for 89.16 percent of the population in Uintah County. This compares to 97.4 percent for Utah. Utah has an extremely homogeneous population. Uintah County has the large concentration of Indians because of the reservation's location. Other ethnic groups combined account for only 0.30 percent of Uintah County's population.

e. Education Levels

Educational levels in the past for Uintah County have been well below the state's. This is reflected in the median years of education in 1960 for Uintah County of 11.7 as compared to the state's median of 12.2. The County has been closing this gap, however, and in 1970 had 12.3 median years of education versus the state's 12.5. Table II.E.6 shows the educational attainment of persons 25 years and older in Uintah County and Utah. Uintah County still lags behind in education, especially

TABLE II.E.5 Ethnic composition of the population of Uintah County and Utah, 1970

	Uintah County		Utah	
	Number	Percent	Number	Percent
White	11,309	89.16	1,031,926	97.4
Black	2	0.02	6,617	0.6
Indian	1,337	10.54	11,273	1.1
Other	36	0.28	9,457	0.9

Sources: U.S. Department of Commerce, Bureau of the Census, 1970 Census of Population; Western Environmental Associates, Inc., 1975a.

TABLE II.E.6 Educational attainment of persons 25 years and older in Uintah County and Utah, 1960 and 1970

	TOTAL	School Years Completed			Median 1970	Median 1960
		Less than 5 years	High School	College		
Uintah Co.	5,994	2.1%	59.4%	8.6%	12.3 yrs	11.7 yrs
Utah	492,337	2.0%	67.3%	14.0%	12.5 yrs	12.2 yrs

Sources: U.S. Department of Commerce, Bureau of the Census, 1967 and 1972 County and City Data Book; Western Environmental Associates, Inc., 1975a.

college education. Only 8.6 percent of Uintah County residents have completed college as compared to 14.0 percent for the state. This can be in part attributed to the concentration of native Americans on the Uintah-Ouray Indian Reservation, part of which is located in Uintah County.

f. Family Size

Family size as reflected by persons per household has decreased from 1960 to 1970 for both Uintah County and Utah. Table II.E.7 shows that Uintah County had 3.96 persons per household in 1960, decreasing to 3.68 in 1970. Reflecting this same trend, Utah had 3.62 persons per household in 1960 and only 3.46 in 1970. In both 1960 and 1970 Uintah County averaged more persons per household than the state. The fact that this area is predominantly Mormon could affect the family size because of the emphasis placed on the family by the Church of

TABLE II.E.7 Number of families and persons per household for Uintah County and Utah, 1960 and 1970

	Families		Persons/Household	
	1960	1970	1960	1970
Uintah County	2,605	3,013	3.96	3.68
Utah	209,373	249,741	3.62	3.46

Sources: U.S. Department of Commerce, Bureau of the Census, 1960 and 1970 Census of Population; Bureau of Economic and Business Research, University of Utah, 1974 and 1975 Utah Economic Business Review, Salt Lake City, Utah; Western Environmental Associates, Inc., 1975a.

Latter-Day Saints. Also affecting the larger family size is the Indian population in the county, although no figures are available at present on family size of native Americans.

2. DISTINCT SETTLEMENTS OF ETHNIC AND ECONOMICALLY DEPRIVED GROUPS

The only significant concentration of a minority group in Uintah County is on the Uintah and Ouray Indian Reservation, part of which is located within Uintah County. The Indian population in 1970 was 1,337 persons (10.54 percent of the county's population). The Indians on the reservation have won several land claims against the U.S. Government that have resulted in sizable monetary settlements.

Bennett (1961-62) states that the Ute Indians are living at a standard of living higher than any they have ever enjoyed. Tribal enterprises (the Bottle Hollow Resort Complex, the Ute Scientific Laboratory, Ute Fabrication, and the Ute Livestock Enterprise) are being developed to help increase revenues and provide jobs. Bennett (1961-62) feels that tribal economic security can be built on industry and tribal enterprises. No doubt their economic stability will be greatly enhanced with future oil development in the area.

Tables II.E.8 and 9 show revenues and expenditures for 1973-74 for the Ute Indian tribe on the Uintah-Ouray Reservation. It is interesting to notice that the largest single source of revenue (\$1,757,969) is from oil and gas concerns. If the oil industry continues to expand in the area, the Indian population would undoubtedly benefit economically.

Table II.E.9 shows expenditures for the Ute tribe totaling \$2,951,847 for 1973-74. This left the tribe with a surplus of \$334,245 for that year. Economically, the tribe appears to be in good condition. Each

TABLE II.E.8 Revenues for Ute Indian Tribe, Uintah and Ouray Reservation, 1973-74

Revenue	Amount
Total Revenue	\$3,286,092
Oil and Gas	1,757,969
Grazing	31,760
Land Lease	59,691
Timber Sales	17,062
Interest on Treas. Fund	1,200,000
Misc. Treas. Collections	9,200
Local Income	
Rent - Homes and Buildings	4,411
Dividends - Dist. Corp.	88,814
Laundromat	10,709
Court Fines	16,367
Fish and Game	18,511
Casting Shop	3,253
Interest - CDs	42,000
Other Interest	25,000
Misc. Local Inc.	1,285

Sources: Unpublished budget data sheets obtained from Ute Tribe Office in Ft. Duchesne, Utah, April, 1975; Logan et al., 1976.

TABLE II.E.9 Expenditures for Ute Indian Tribe, Uintah and Ouray Reservation, 1973-74

Expenditure	Amount
Total Expenditures	\$2,951,847
General Administration	(865,515)
Business Committee	171,527
Tribal Attorney	45,000
Administration	102,716
Public Relations	25,553
Treasurer	150,799
Budget and Account	90,139
Maintenance	263,022
Contribution to Government	16,759
Social	(585,144)
Community Building	37,863
Tribal Court	43,048
Juvenile Court	18,589
Law and Order	130,856
Environment Health	72,865
Education and Employment	77,071
Alcoholism	71,685
Rehabilitation Projects	24,348
Senior Citizens	17,700
Recreation	76,004
Youth Camp	10,000
Economic	(270,367)
Service Station	20,753
Forestry	11,000
Crafting Shop	30,079
Resources	112,872
Fish and Game	95,663
General Membership	(870,500)
Services and General Expense	48,000
Dividend Payment	822,500
Capital	(360,321)
Land and Stock	360,321

Sources: Unpublished budget data sheets obtained from Ute Tribe Office in Ft. Duchesne, Utah, April, 1975; Logan et al., 1976.

member receives an income of approximately \$4,500 per year based on a land settlement with the Federal Government back in the 1950's. At present the tribal population is between 1,500 and 1,600.

Impact on the Ute Indian tribe is currently being studied in relation to the Ute Indian Unit of the Central Utah Water Project. This project along with future energy demands could have a dramatic effect on the traditional lifestyles of the Indians. It will be up to the Tribal Business Committee to decide the fate of their tribe. It appears, however, that economic growth will be incompatible with traditional lifestyles.

The Utes are currently suing the Federal Government for control over the original boundaries of the Indian Reservation. This would include most or all of Duchesne, Uintah, and Daggett Counties. The old reservation boundaries encompass the majority of the oil, oil shale, and tar sands found in Utah. The Indians could conceivably play a decisive role in energy development in the Uintah Basin.

Tribal enterprises, industry, and resource development represent westernized (Europeanized) ways of life. Adoption of Western culture has and will have serious detrimental effects on the Indian population. The idea of acculturation of various groups into the great American melting pot has been challenged recently as not necessarily desirable.

3. ECONOMIC HISTORY AND EMPLOYMENT

Anglo settlement of the Uintah Basin did not begin until 1877. The economy was basically dependent on agriculture, although initially the territories were important for trapping and furs. This is a pattern found throughout the west. Agriculture was the important aspect of the Uintah County economy, with potatoes, garden produce, pork, poultry,

eggs, butter, sheep and cattle being the major products of the area. Substantial growth in the economy did not occur until the 1940's when oil was discovered in Uintah Basin. Since 1970 rapid growth has occurred because of increased oil exploration and production. The Utah State Planning Coordinator (1975) projects a population decline of 7.11 percent from 1975 to 1980 for the Uintah Basin multicounty district (Uintah, Duchesne, and Daggett Counties). This decline is based on the following assumptions: (1) oil exploration will peak and then decline in the area; there will be (2) no oil shale development, (3) no phosphate expansion, (4) no oil refineries built, (5) no tar sands development, and (6) no Central Utah Water Project. Continued decline in the population is projected through 1990 for the Uintah Basin if no development in these areas takes place.

There are several problems associated with using these population figures for "future zero" with their projected decline. First and foremost is the complexity of the simulation model used to predict these population increases and decreases. The model (Utah State Planning Coordinator, 1975) deals with 44 major developments that can occur in combinations of 10 "alternative futures." Occurrence of one variable in one section of the state can affect the population and employment in other areas as well. The second problem is in defining the most likely set of events for "future zero." "Future zero" is not defined by projection of past trends, but by what is most likely to occur in the area. Obviously, this is a very difficult thing to define. The third problem with using "future zero" for baseline population figures is that because of the number of variables involved and the interaction of these variables

it is likely that some event either named or not in Alternative Futures (Utah State Planning Coordinator, 1975) has occurred and thus invalidated "future zero" projections. If not, there is certainly this possibility in the future.

If oil shale, oil refineries, phosphates, water projects, and tar sands are not developed in the area we can expect a decline in population; this also assumes no other development outside the Uintah Basin that might affect the area indirectly. There are simply too many variables involved to safely predict a population decrease of such a magnitude in an area with the mineral wealth that is found in the Basin area.

Recent moves by industry as well as the federal government have opened the door for development of oil shale. Development Engineers Inc. are operating the Anvil Points research site under a Navy contract. The C-b oil-shale group (Occidental and Ashland) are preparing their lease tract for initial operations and the C-a oil-shale group (Gulf and Standard-Indiana) are waiting for final approval of their plan. Occidental is also continuing with their research and development activities in the Logan Wash on private land. Using these recent developments as an indication, we can expect the oil shale deposits in and near ... Uintah County to be developed in the future. White River Oil Shale Co. has commissioned a socioeconomic evaluation of possible impacts to the area of oil-shale development in the region.

The study by Western Environmental Associates, Inc. (1975), included possible impacts to three counties, Uintah and Duchesne in Utah and Rio Blanco in Colorado. Most important were their population and employment projections attributable to oil-shale development. Table II.E.10 shows

TABLE II.E.10 Gravity model distribution of population impact among principal urban places in Rio Blanco, Duchesne, and Uintah Counties

Year Commercial Stage	Cumulative Total Population Impact	Duchesne	Roosevelt	Vernal	Rangely	At or Near Site	Other Parts of Uintah Basin
Phase I							
5	4,538	152	500	1,257	1,713	688	227
6	6,218	206	678	1,704	2,324	994	311
7	8,277	277	911	2,290	3,121	1,265	414
8	13,780	485	1,595	4,010	5,466	1,536	689
9	11,310	419	1,376	3,461	4,718	770	566
10	10,902	412	1,354	3,405	4,641	545	545
Phase II							
11-15	12,535	479	1,574	3,958	5,396	501	627
16-20	12,535	479	1,574	3,958	5,396	501	627

Source: Western Environmental Associates, Inc., 1975b.

a gravity distribution of population due to the development of oil shale in Uintah County. Absent from the table is the construction phase population which would go from the initial level of 924 in the first year to 1,305 in the fourth year of development. These numbers represent total number of in-migrants including construction workers and families as well as service employees and families. Construction phase population projections were not distributed among the urban centers in Table II.E.10 because it is expected that a sizable number of these workers will live at the site in a construction camp or similar facility. Table II.E.11 shows the employment needs for each year of development of a commercial oil-shale operation along with indirect service employment and the total population increases expected each year of development.

If the present trend continues in the area in terms of energy development, we can expect increased reliance on the oil industry and related fields as the industrial base for the area. Table II.E.12 shows employment distribution in Uintah County, Utah, and the U.S. for 1960 and 1970. The decline in agriculture, forestry, and fisheries workers from 19.15 percent of the employed population in 1960 to 11.8 percent in 1970 indicates the relatively large number of people in agriculture as well as sharp decrease (38.4 percent) for that sector of the economy in that decade. Even with the 38.4 percent decrease from 1960 to 1970, 11.8 percent of the employed people involved in agriculture in Uintah County is a much larger percentage than the state average for the same year of 3.8 percent. Also representing this trend is the percent of rural farm dwellers for Uintah County (16.1 percent) in 1970 versus 2.4 percent rural farm dwellers for the state of Utah (Table II.E.2).

TABLE II.E.11 Annual population impacts of the White River Oil Complex on Duchesne, Uintah, and Rio Blanco Counties

Year Commercial Development Stage	Construction Based	Operations Based	Indirect Based	Total
1	600	--	324	924
2	600	--	324	924
3	--	870	348	1,218
4	--	870	435	1,305
Commercial Stage Phase I				
5	2,030	792	1,716	4,538
6	3,050	792	2,376	6,218
7	3,960	771	3,546	8,277
8	2,865	2,765	6,150	13,780
9	940	3,880	5,490	11,310
10	--	5,451	5,451	10,902
Commercial Stage Phase II				
15	--	5,014	7,521	12,535
16	--	5,014	7,521	12,535

Source: Western Environmental Associates, Inc., 1975b..

TABLE II.E.12 Percent distribution of employed persons by industry group for Uintah County, Utah, and the U.S., 1960-1970

	Uintah		Utah		U.S.	
	1960	1970	1960	1970	1960	1970
Agriculture, Forestry, Fisheries	19.5	11.8	6.1	3.8	6.7	3.7
Mining	16.3	17.5	4.4	3.1	1.0	0.8
Construction	9.2	6.5	6.9	5.4	5.9	5.9
Manufacturing	5.0	5.5	16.0	14.5	27.1	25.9
Retail Trade	15.6	20.0	16.9	17.9	15.6	16.8
Railroad & Railway	--	--	2.9	1.5	1.5	0.8
All Other	34.06	38.5	47.2	53.3	42.2	45.8

Sources: U.S. Department of Commerce, Bureau of the Census, 1960 and 1970 Census of Population; Logan et al., 1976; University of Wyoming, Department of Sociology calculations.

An increase in mining employment is also noticeable in Table II.E.12 (from 16.3 percent in 1960 to 17.5 percent in 1970, an increase of 7.1 percent), although much of the development of natural resources in the area has occurred since 1970. More recent figures would show a faster growth rate for this sector of the economy.

Recent figures are available for unemployment rates for Uintah County and Utah (Table II.E.13). Since 1971 Uintah County's unemployment rate has been decreasing more rapidly than the state's. In 1973 the county's low unemployment rate (3.5 percent) is considered to be due to frictional unemployment, therefore indicating a situation of full employment. The low unemployment rate can be attributed to development of natural resources in the area and can be expected to remain low given

TABLE II.E.13 Population, civilian labor force, and unemployment rate for Uintah County and Utah, 1970-1973

	Population	Civilian Labor Force	Unemployment Rate
Utah			
1970	1,066,000	415,900	6.1%
1971	1,085,000	432,200	6.6%
1972	1,128,000	454,160	6.2%
1973	1,150,000	480,400	5.8%
Uintah County			
1970	12,800	4,750	5.9%
1971	13,300	5,140	6.0%
1972	14,400	5,880	4.4%
1973	15,200	6,260	3.5%

Sources: Utah Department of Employment Security 1974, Bureau of Business and Economic Research, University of Utah, Salt Lake City; Western Environmental Associates, Inc., 1975a.

stable growth in these industries. If, however, population actually declines as predicted in "Future Zero," we can expect a rise in the county's unemployment level.

4. INCOME LEVELS

Median incomes in Uintah County were lower than the median incomes for both the state of Utah and the United States in 1960 and 1970 (Table II.E.14). Also, Uintah County had a higher percentage of families living below poverty line than both Utah and the United States in 1970 (13.9 percent as compared to 9.1 percent and 10.7 percent, respectively). This larger concentration of families below the poverty line could be due to the high concentration of native Americans living in the county. This concentration of a low-paid, less productive group with a high unemployment rate would also be reflected in the low median incomes.

TABLE II.E.14 Median income, percent of families with income of less than poverty level and \$15,000 (10,000)* or more: United States, Utah, and Uintah County, 1960 and 1970

	1960			1970		
	Families with Incomes			Families with Incomes		
	Median Income	Less than \$3,000	\$10,000 or More	Median Income	Less than Poverty Level	\$15,000 or More
United States	\$5,620	21.7%	14.3%	\$9,867	10.7%	22.3%
Utah	\$5,899	14.7%	13.8%	\$9,320	9.1%	17.0%
Uintah County	\$5,281	20.4%	9.3%	\$8,082	13.9%	11.0%

*\$15,000 for 1970 and \$10,000 for 1960.

Sources: U.S. Department of Commerce, Bureau of the Census, 1960 and 1970 Census of Population; Western Environmental Associates, Inc., 1975a.

Not directly related, however, to the Indian population is the low percentage (11.0 percent) of families making over \$15,000/year in Uintah County as compared to 17.0 percent for Utah and 22.3 percent for the United States. This low concentration of people in the higher income bracket is probably a function of the type of employment available in the Uintah Basin prior to 1970.

Table II.E.15 shows the average monthly nonagricultural wage by major industry for Utah and Uintah County. The average monthly wage for manufacturing is only \$482 as compared to \$714 for the state. Differences such as these have a detrimental effect on the median income of a community. Also affecting the lower median income for Uintah County is the relatively high concentration of persons involved in agriculture. Figures on incomes for these people are not available at this time.

TABLE II.E.15 Average monthly nonagricultural payroll wage by major industry division for Utah and Uintah County, 1973

	Utah	Uintah County
Manufacturing	\$714	\$492
Mining	\$949	a
Construction	\$813	a
Transportation	\$885	\$778
Trade	\$481	\$510
Finance	\$585	a
Services	\$452	\$460
Government	\$680	\$622
Total	\$624	\$620

a = Not published to avoid disclosure of individual firm data.

Sources: Utah Department of Employment Security, Utah Labor Market Information by Planning District and County, 1950-1973, Salt Lake City, 1974; Western Environmental Associates, Inc., 1975a.

The oil industry and other resource-recovery industries appear to be having a positive effect on average monthly income of workers in Uintah County. Although specific figures are not available for average monthly wages paid mining and construction personnel, the total average monthly wage is a good measure. Uintah County's average monthly wage for nonagricultural workers for 1973 was \$620 as compared to \$624 for Utah as a whole. This increase in average monthly wage for Uintah County can probably be attributed to increased resource recovery in the area.

5. LAND VALUES

Uintah County is composed of 4,487 square miles with a population density of only 2.8 people per square mile in 1970; 64.9 percent of the land within Uintah County is owned by the federal government, 14.4 percent is Indian land, and 8.1 percent is state land. Therefore, only 12.2 percent of the land in Uintah County is privately owned, with the remainder belonging to cities, towns, and the railroads. This percentage is much less than that of surrounding Duchesne County (37.6 percent) or of the state as a whole (21.5 percent). Because of this, available land in the county could be more expensive than in surrounding areas.

Residential land prices appear to be similar throughout the region. A residential lot within the city limits of Vernal is approximately \$6,000 for one-third of an acre. A slightly larger lot within the county but with city water would be \$5,500 (approximately one-half acre). A residential lot in Maeser would average \$7,000 (for three-quarters of an acre) but land ownership in this area is tightly held.

6. FISCAL MANAGEMENT

As of January 1976 Uintah County had an overall assessed valuation of \$51,404,700. Table II.E.16 indicates the assessment level as well as the effective tax rate for Uintah County. The county had no bonded indebtedness as of January 1, 1976.

Uintah County operates on calendar years instead of fiscal years. The last available budget report is for the year ending December 31, 1975. The budget report for the year ending December 31, 1976, is currently being audited and is unavailable. Total expenditures and revenue for the General Fund are shown in Table II.E.17 for 1974 and 1975. The table

TABLE II.E.16 Assessment levels and effective tax rate on property in Uintah County, 1976

	Indicated Assessment (% of fair market value)	1974 Effective Tax Rate
All Locally Assessed Property:		
County Average	16.91	1.03
<u>Improved Real Estate</u>		
Residential	19.83	1.20
Commercial	14.93	.91
<u>Unimproved Real Estate</u>		
City and County Lots	18.13	1.10
Parcels over Five Acres	13.21	.80
Total Mill Levy Outside of Cities and Towns, 1975		60.62

Source: Utah Industrial Development Information System, Uintah County: County Economic Facts, County Courthouse, Vernal, Utah, 1976.

TABLE II.E.17 General Fund revenues and expenditures for Uintah County for 1974 and 1975

	Fund Balance from Previous Year	Revenues	Expenditures
1974	\$286,454.00	\$1,227,189.00	\$1,399,574.00
1975	252,672.00	1,715,366.00	1,472,017.00

Source: Uintah County Courthouse, County Clerk's Office.

covers only the General Fund for comparison purposes. Other funds in the county are: Special Revenue Funds, Debt Service Funds, Capital Projects Funds, and the Special Service Enterprise Fund.

Expenditures for 1974 are covered by the fund balance carried over from the previous year. Revenues have increased from 1974 to 1975 by 39.8 percent. At the same time expenditures in the general fund increased by only 12.3 percent. Without the 1976 budget report it is difficult to generalize about the county fiscal situation. It does appear, however, that the county is at present in good economic condition.

Vernal, which is the county seat for Uintah County, operates on fiscal years, unlike the county. Table II.E.18 shows revenues and expenditures for Vernal's General Fund from 1975 to 1977 with estimates for 1978. Although expenditures are greater than revenues for 1975 and 1976, this does not indicate that the city was operating in the red. Vernal has a surplus carried over from previous years that covers situations where expenditures are greater than revenues. In addition to the General Fund, Vernal also has a Utility Fund. Table II.E.19 shows revenues and expenditures for this fund from 1975 to 1977 with 1978 estimated. Vernal officials are interested in expanding water and sewer facilities with the cooperation of the county and other communities within the county to offer water and sewer to all residents. (At present Vernal does make its water available to nearby county residents.) At present Vernal's Utility Fund appears to be in sound financial condition. However, future demand on the sewer system will necessitate expansion of the old facility. If the countywide sewer system is built it appears that a bond issue will have to be passed to finance the new construction.

TABLE II.E.18 General Fund revenues and expenditures for Vernal,
FY 1975-1978

	Revenues	Expenditures
FY 1975	\$607,807	\$609,434
FY 1976	\$573,165	\$613,132
FY 1977	\$740,523	\$697,705
FY 1978 (estimated)	\$787,106	\$729,010

Source: Vernal City Hall, Michelle Acock.

TABLE II.E.19 Utility Fund revenues and expenditures for Vernal,
FY 1975-1978

	Revenues	Expenditures
FY 1975	\$520,039	\$271,487
FY 1976	\$510,194	\$499,409
FY 1977	\$832,450	\$732,450
FY 1978 (estimated)	\$750,700	\$750,600

Source: Vernal City Hall, Michelle Acock.

7. HOUSING

Uintah County. There were 3,700 housing units in Uintah County in 1970; this increased 51.7 percent by 1975, to 5,613 (see Table II.E.20). Mobile homes accounted for 679 of the new units, or 35.5 percent of the growth. In 1970, 8.0 percent of housing units were mobile homes; by 1975 this figure had increased to 17.4 percent (compared to 2.6 percent for

TABLE II.E.20 Selected housing characteristics for Uintah County and Utah, 1970 and 1975

	Uintah County		Utah
	1970 ^a	Jan. 1975	1970 ^a
Total Year-Round Housing Units	3,700	5,613 ^b	311,814
Single Family Units			
Number	3,130 ^c	NA	234,484
Percent	84.6	NA	75.2
Multiple Family Units			
Number	570	NA	77,330
Percent	15.4	NA	24.8
Mobile Homes			
Number	297	976 ^b	8,232
Percent	8.0	17.4	2.6

^a U.S. Department of Commerce, Bureau of the Census, 1970 Census of Housing.

^b From an unpublished study done by Mr. Jerral L. Syme, Planning Advisor for Uintah Basin Association of Governments.

^c Includes only occupied mobile homes

Sources: Logan et al., 1976.

the state in 1970; we do not expect the state percentage to have changed substantially since 1970). The rapid increase in mobile homes can be attributed to rapid growth in the oil industry in the area. This is characteristic of towns undergoing faster than average industrial development.

Vernal. A housing survey carried out by the Vernal City Planner's Office in 1974 identified 1,754 housing units within the limits. Of these, 1,091 were conventional single-family dwellings, 324 were mobile homes (18.5 percent of all dwelling units were mobile homes), and 339

were multiple-family units (19.0 percent of all dwelling units were multi-family units). The study also classified housing units as sound (86.4 percent), deteriorated (12.1 percent), or dilapidated (1.5 percent). This portion of the study excluded mobile homes since they were relatively new.

8. HEALTH AND SOCIAL SERVICES

a. Health Care

Because Vernal is the population and service center for Uintah County, statistics on health services for Vernal are used here.

As of 1976, Vernal had seven practicing physicians for a doctor to population ratio of 1:929. A ratio of 1:1,000 is recommended by the U.S. Department of Health, Education and Welfare. Vernal has 15 nurses for a nurse to population ratio of 1:433 (1:285 is recommended by HEW). Five dentists in Vernal yield a dentist to population ratio of 1:300 where HEW guidelines call for a ratio of 1:1,600. Therefore, Vernal appears to be in good shape medically with the exception of nurses.

Vernal is served by Uintah County Hospital with a 31-bed capacity. It is expected that a bond issue will have to be passed to finance a half-million dollars worth of remodeling for the present hospital.

b. Law Enforcement

Vernal has 15 full-time law enforcement employees for 2.3 policemen per 1,000 population. According to the FBI (Kelley, 1975), cities with populations under 10,000 average 2.3 law enforcement employees per 1,000 population. The national average for law enforcement personnel to population was 2.5:1,000 (Kelley, 1975:222).

Uintah County had nine full-time law enforcement officers in 1976. This yields a ratio of .81:1,000 law enforcement employees to population. The average rate of full-time employees in sheriff's departments was 1.6 per 1,000 inhabitants (Kelley, 1975:233). It must be realized, however, that smaller rural communities rely less on law enforcement personnel and more on informal sanctions in the community. Therefore, small counties, cities, and towns in rural areas need fewer law enforcement personnel per 1,000 inhabitants than larger industrialized and urbanized areas.

c. Fire Protection

Vernal does not at present have a full-time fire department. The city is served by a volunteer fire department. Uintah County is also served by a volunteer fire department. Statistics on the number of volunteer firemen for the city and the county are unavailable at this time.

d. Water Supply

The city of Vernal receives its water from a series of springs in the area. The water requires no treatment other than chlorination. The existing system is now serving approximately 14,000 inhabitants in the city and county. There is no problem with the present water system. It is felt that the system could supply water for 35,000 inhabitants without major changes. Maeser, a small town between Vernal and the LERC tar sands site, has its own water system. It is also hoped that the communities in Uintah County could develop a countywide water system.

e. Sewage Treatment

At present the Vernal sewage disposal system is inadequate. Designed for a population of 6,000, it is estimated that as many as 7,000 inhabitants are currently using the system. The city is planning a new lagoon system with a capacity for 35,000 people and hopes to start on it within 24 months.

There has been some talk of developing a countywide sewer system as well as a countywide water system, but as yet county residents must still rely on septic tanks.

9. EDUCATION

Uintah County School District serves the area with five elementary schools, two junior highs, one high school, and one learning center for the handicapped. Table II.E.21 shows the 1976 enrollment for each school. There are 2,542 elementary students in the school district. The newest elementary school has recently been completed in Maeser and has a capacity of 650 students. Secondary schools in the district have 2,217 students. The senior high, located in Vernal, has an enrollment of 834 students.

There are no colleges or universities within Uintah County. The nearest college is Rangely College located 60 miles east of Vernal in Rangely, Colorado. The College of Eastern Utah is located in Price, 120 miles from Vernal. The nearest university is Brigham Young University in Provo, 150 miles from Vernal.

A trade and vocational school is located near Vernal (Uintah Basin Vocational Center) and has an enrollment of 765 students.

TABLE II.E.21 Enrollment in schools in the Uintah School District,
1976

<u>School</u>	<u>Enrollment</u>
<u>Elementary</u>	
Ashley	570
Central	437
Maeser	562
Naples	453
Todd	520
TOTAL	2,542
<u>Junior High</u>	
Vernal Junior	912
West Junior	277
TOTAL	1,189
<u>High School</u>	
Uintah	834
<u>Learning Center</u>	
New Life Learning Center	35
GRAND TOTAL	4,600

Sources: Uintah County School District, 1976, and Phillip Ellis.

10. TRANSPORTATION

Vernal is located on highway U.S. 40, Utah 44 and Utah 121. The LERC tar sands site is directly off Utah 121 four miles west of Vernal. Interstate 80 is 112 miles to the north; Interstate 70 is 80 miles from the city.

No railroad serves Uintah County, although at one time a narrow-gauge railroad was used for hauling gilsonite. The nearest railhead is Green River, Wyoming, which is 112 miles from Vernal, or Price, Utah, which is 120 miles from Vernal.

Air transportation is provided by Frontier Airlines. This is a feeder service to major airports in Salt Lake City and Denver. The area is also serviced by two charter airline companies, Basin Flying Service and Dinaland Aviation, Inc. Helicopter service is available but the home bases are located in the larger cities in Utah and Colorado. The Vernal airport does have a lighted 6,600-foot runway.

11. COMMUNITY ATTITUDES

Information from the Utah Community Progress Survey conducted by the Adult Education Center in Roosevelt, Utah, indicates a perceived need for (1) more effective and coordinated government, especially in relation to the control of development-induced growth through zoning; and (2) more and better housing (ratings in this area were lower than any other area). Asked to list three projects they thought would help their community in the next few years, the sample population listed the following. (The frequency of each response is given in parentheses; total number of respondents = 400.)

1. Improved streets and roads (98)
2. Better and more water (40)
3. Beautification project (30)
4. Recreation facilities (29)
5. More local activities for youth (24)
6. Shopping conveniences (24)
7. Parks and park beautification (14)
8. Better or new library (10)
9. Better housing (9)
10. Baseball complex (8)
11. Indoor-outdoor swimming pool (8)

12. Mail home delivery (8)
13. Zoning and land use planning (8)
14. Better sewer (7)
15. Law enforcement (6)
16. Bowling (5)
17. Senior citizen program (5)

In the response to the question, "Would you be willing to pay more taxes if you knew that money would be spent in your community for that particular purpose?," "yes" was indicated by the majority of respondents for (a) better education, (b) improved water systems, and (c) improved streets and roads; "no" was indicated by the majority of the respondents for financing (a) low-income housing, (b) training for local government officials, and (c) development of an industrial site.

A study by Western Environmental Associates, Inc. (1975), indicated general support for resource development and economic growth in the area. The question "Do you approve or disapprove of oil shale development in the Uinta Basin?" was answered affirmatively by 82 percent of the Vernal respondents. Most of those who did not approve of the development stated they were undecided rather than opposed.

Table II.E.22 shows the relationship of several demographic variables and perceptions of change associated with economic growth. The length of time one has lived in a community affects one's perception of economic growth as good or bad: the longer one has lived in the community the less likely he is to perceive growth as having made the area a better place to live. This is also indicated by the fact that newer residents value growth in the community whereas older residents value the traditional rural lifestyle.

TABLE II.E.22 The relationship between selected demographic variables and perceptions of change associated with economic growth

	Growth has made the area a better place to live	Growth has made the area a worse place to live
<u>Years in the Community</u>		
0 - 5	82%	18%
6 - 10	67%	33%
Over 10	57%	43%
<u>Religion</u>		
Mormon	62%	38%
Non-Mormon	86%	14%
<u>Age</u>		
25 and under	78%	22%
26 - 35	66%	34%
36 - 45	75%	25%
46 - 55	63%	37%
56 - 65	61%	39%
65 and over	35%	65%

Sources: Logan et al., 1976; Western Environmental Associates, Inc., 1975b.

Also related to traditional rural lifestyles is religion. Mormons settled the area originally on a sound agricultural base. Recent oil and resource industry exploration and expansion has brought in outsiders and shifted the economy to resource-recovery industry. Therefore, we would expect non-Mormons to value economic growth more than Mormons, as indicated in the table. It is the traditional rural Mormon lifestyle that is being changed.

Age is also an important demographic variable in perceptions of economic growth. Workers moving into an area for employment are more likely to be young and have positive attitudes about economic growth

since they are benefiting from such growth. Also, when younger local residents do not need to leave the community to find employment they are more likely to view the economic growth as beneficial. Generally the older one becomes the less likely he is to perceive himself as benefiting from economic growth in the community. The figures in Table II.E.22 reveal this relationship; as age increases each age group will increasingly view economic growth as having negative impacts on the community.

In summary, older, Mormon, long-time residents do not perceive economic growth as affecting the community as positively as the younger non-Mormons who have recently moved to the area (last five years). This latter group are more positively oriented toward future economic and population growth. At present there is no attitudinal data on the native American and reservation population.

12. SUMMARY OF CRITICAL SOCIOECONOMIC AREAS

Population. A critical factor for the Uintah Basin multicounty district is a projected population loss of 7.11 percent from 1975 to 1980 as projected by the Utah Process in Alternative Future Zero (Utah State Planning Coordinator, November 1976 revision). This population loss will affect the community negatively because of decreased economic activity, decreased tax base, a glutted housing market, and the general representation of an area in decline.

This projected "Alternative Future Zero" is based on the most likely set of events, which includes continued and expanded petroleum exploration and drilling for a short time, after which drilling is expected to decline but basic employment will be sustained somewhat by production rather than exploration. In "Future Zero" no dewaxing plant, oil refinery

expansion, or pipeline is included. Also, no development of tar sands or oil shale deposits is included.

Decline in the population is the result of cancellation of the Karparowits power plant project in southwestern part of the state (Kane County). With the Karparowits project included in "Alternative Future Zero" the multicounty Uintah Basin district was expected to increase in population by five to 10 percent between 1970 and 1980, after which population would decline from 0 to 2.1 percent annually from 1980 to 1990.

Undoubtedly, this revised projection of a declining population rate of 7.11 percent between 1975 and 1980 and 7.94 percent between 1980 and 1985 will have a detrimental effect on the community if it is realized. The main negative effect will be economic in nature, impacting retail trade, housing, and the tax base.

With the current emphasis on energy development, the recent approval of an oil-shale project in Colorado, and the possibility of the Central Utah Water Project being funded, it appears that the Uintah Basin will not have to contend with a declining population. Oil-shale development in the region will undoubtedly have an effect on Vernal and Uintah County as well as the Uintah Basin as a whole. If oil-shale deposits in the basin are developed, we can expect the population increase due solely to oil shale to peak at around 13,780 then level off to 12,535 in the second phase of the commercial stage.

Agriculture. One area undergoing transition in Uintah County is the agricultural sector. In 1960, 21.9 percent of the residents of Uintah County were rural farm dwellers; this percentage decreased to

16.1 percent by 1970, representing a decline of 26.5 percent in rural farm dwellers. The percent of employed persons engaged in agriculture, forestry, and fisheries has decreased by 38.4 percent between 1960 and 1970 (from 19.15 percent of the employed population to 11.8 percent).

This indicates a growing reliance on the oil industry and less reliance on agriculture. This change will be manifested as rural, traditional lifestyles are supplanted by new ways of life more compatible with industrialization. One of the things valued by long-time residents of the area, as pointed out by the attitudinal survey conducted by Western Environmental Associates (1975), was the traditional rural lifestyle, which may be incompatible with economic growth. If economic growth continues, it may be at the expense of traditional rural lifestyles.

Housing. Much of the increased demand for housing in the past has been met by mobile homes (17.4 percent of all housing in Uintah County is mobile homes as compared to a state average of 2.6 percent in 1970). Although information is scarce it was pointed out by the Vernal City Planner that the city was experiencing a shortage of rental units.

Since the county has weaker zoning laws than the city and city water is available in the county a situation has been set up where the city is losing its population to the county. Rural nonfarm residents in Uintah County in 1970 comprised 51.2 percent of the population (as compared to only 17.0 percent of the population of the state as a whole). This development has been propagated by the absence of comprehensive zoning laws, the availability of less expensive land, and the availability of city water. If this trend is allowed to continue, it will result in haphazard development around Vernal.

Health Care. Vernal has a doctor to population ratio and dentist to population ratio better than that recommended by HEW. The nurse to population ratio, however, is only 1:433, where HEW recommends 1:285. Translated into numbers, this means Vernal is short eight nurses. To maintain the ratio recommended by the U.S. government there should be 23 nurses instead of the 15 presently in Vernal.

Sewage Treatment. The sewer system is operating at or above capacity at present. The present system was designed to accommodate a population of 6,000. The 1976 estimated population for Vernal was 6,500. The City Planner for Vernal estimated that the present system is serving approximately 7,000 residents at present. A new lagoon system is being designed for the city. It is expected that the new project will be started within 24 months. The new sewage treatment facility will have a maximum capacity for a population of 35,000.

Education. Uintah County School District is currently operating at capacity. A relocatable classroom has been brought in to use at one of the elementary schools to help relieve the burden. There is only one high school now serving the entire county. A bonding issue that would have provided for two new high schools failed in May of 1977. Had the two new high schools been built, the old high school would have been turned into a middle school, thus relieving some pressure on the elementary schools.

Thus, school district officials indicate that with the existing schools they could not accommodate a substantial increase in the number of school children.

CHAPTER III

POTENTIAL IMPACTS AND MITIGATIONS

A. AIR QUALITY

1. PRE-OPERATIONAL PHASE

Air quality would deteriorate during the construction phase due to two sources of emissions: exhaust gases from transportation and construction vehicles, and fugitive dust created by earth moving and vehicles. Because of the small size of the research projects, with only about 10 vehicles per day contributing to the pollution, the impact is not considered to be serious. Methods of mitigation include air pollution control devices on engines and surface treatment (e.g., water or oil) of road and landscaped areas to reduce dust. These impacts should be short-term, less than six months, and no long-term or cumulative impacts are anticipated.

2. OPERATIONAL PHASE

Air quality would deteriorate more seriously during the operational phase of the research project. Emissions and dust due to vehicular use would continue, and additional amounts of air pollution would be created by well-boring equipment and by venting of the gases produced by the process. The vented or flared gas contributes probably the largest steady source of emissions; certainly this source will be a major concern for the large-scale operations; for this small research project, with total gaseous emissions on the order of a thousand SCFM, air quality problems

are anticipated only in the immediate vicinity of the stack. The use of an electrostatic precipitator reduces the particulate stack emissions; gas scrubbers may also be warranted if the composition of the flare gas indicates large quantities of critical pollutants.

The gaseous emissions from the stack are typical of combustion products from fossil fuel in the presence of excess O_2 . Full gas characterization is not available from only the first burn of 1976 as a data source. Gases will be characterized for the following: sulfur oxides, nitrogen oxides, CO, unburned hydrocarbons, methane, and particulates.

Additional data are needed on the characterization of the vent/flare gas composition and quantity (from each burn), stack height and diameter, exit velocity, etc., in order to estimate the downwind concentrations of emission products. Furthermore, some verification of existing dispersion models is needed to justify their use in a region of non-uniform terrain.

Dust and exhaust emissions should be short-term and small in quantity. The flare gas emission will continue for the duration of the research (several years). No cumulative impacts are anticipated.

3. POST-OPERATIONAL PHASE

Short-term impacts include engine exhaust and dust created by earth moving and vehicular operation during the restoration process. These short-term impacts can be reduced by surface treatment of dust-producing areas and by scrubbing and particulate separation of the cooling water products, if warranted. No long-term or cumulative impacts are anticipated.

It should be noted that no reference to possible accidental releases of air pollution could be found in the project description. Some assessment of this possibility is warranted, especially in view of the anticipated large-scale development. For example, accidental explosion and burning of the surface-stored oil could produce a large amount of pollution, substantially greater than the stack emissions. Explosion or earthquake induced breakage of the piping could allow the raw retort gas to escape. Perhaps the possibility of accidents is nonexistent, but the extent of the possibilities should be assessed.

One factor attending air quality alterations which should always be considered (but is difficult to evaluate) is the possible effects of particulates, gases, and atmospheric stability changes upon the precipitation processes which occur in-cloud. Thus, for example, Eagan et al. (1974) found an increase in the concentration of large cloud condensation nuclei downwind of a large kraft paper mill located on the Pacific coast. They asserted that this could lead to decreased colloidal stability of the essentially maritime clouds which injected this air, and it could conceivably increase their natural warm cloud precipitating efficiency. In a recent study of coal-fired power plant effluents in Wyoming and Montana, Cooper and Lukow (1977) found very little increase in the cloud condensation nuclei concentration in the region downwind of the plant stack. The questions of changing the natural precipitation have special importance for this arid region.

B. WATER QUALITY

1. PRE-OPERATIONAL PHASE

In preparation for recovery experiments, land is cleared of vegetation, topsoil is removed and stockpiled, and gravel is placed over the area of activity. The present research site has 6 acres fenced of which about 4 acres are cleared. Access roads are graveled. Tanks for containment of produced oil and water have been placed in a pit that has been excavated several feet and the excavated material has been used as a dike around the pit to contain accidental spills. Several small buildings have been erected or moved onto the site.

One of the effects of these changes is to increase the imperviousness of the area, thereby increasing rainfall and snowmelt volumes and peak flows, plus increasing erosion and sediment, and dissolved solids delivery downstream. These impacts are insignificant on the present research site because the site is small and on a broad ridge where the land is even and nearly flat. In addition, a small dike has been constructed along the lower end of the site to contain runoff and sediment.

On future larger projects these impacts are likely to be significant.

No quantifications of rainfall runoff, soil loss, or sediment delivery have been attempted for research, pilot, or commercial conditions in the area. There are several methods and approaches available to estimate these items, but most of them are not refined enough to estimate accurately the effects of development impacts.

Rainfall-runoff and soil-loss models (Crawford and Linsley, 1966; Smith, 1976) provide the means to quantify the existing conditions and development impacts. These models require calibrations and field data. It is suggested that a hydrometeorological station be established to

measure precipitation runoff and sediment for a small basin in the area. This information would be useful for impact assessment of future research sites in this area. On pilot or commercial projects where impacts on runoff, erosion, and sediment delivery will be significant, such information will be a necessity for environmental impact statements. The baseline data are required before a model can be calibrated and used to estimate the effects of future proposed plans.

During the construction phase of in situ or modified in situ tar sands processes, wells will be drilled. The main materials drilled will be alluvium, conglomerate, sandstones, shale, and tar sands. If a rotary process is used in which drilling mud is required, a slight change in groundwater quality could occur near the hole being drilled. The drilling mud ponds formed on the surface could be a source of pollution to the shallow aquifer system. If the different aquifers are not properly sealed off from one another, water quality changes could occur because of communication in the well holes between aquifers. Since no groundwater is presently indicated at the research site for tar sands, the only effect will be leaching of the mud material left from the drilling operation with time, and as a result the impact should be very minimal. Packing material used in a well and completion procedures could change water quality near a well. The well drilling program at future research sites should be closely monitored to determine if such changes do occur. Current information is lacking in this regard. Care must be taken to seal adjacent aquifers from one another in any future drilling.

The aquifers encountered during drilling in future research studies should be sealed (cemented) from one another to preclude any contamination

between aquifers or the result will be long-term intercommunication and contamination.

The alternatives to actions causing impacts during the pre-operational phase are to use drilling methods which use air injection or other non-polluting fluids and completion procedures for protection against intercommunication and contamination of the aquifers.

Sanitary wastes generated on-site by construction workers will require the use of portable holding tanks. These wastes will be small in volume and will occur only over a short term.

2. OPERATIONAL PHASE

Surface conditions during operations are the same with regard to surface runoff as were described for the pre-operational phase above.

Changes in groundwater quality will occur during in situ combustion of the tar sands. The specific changes which do occur during this phase of operation have not been quantitatively defined. This is not a problem at this research site because it is indicated that no groundwater exists below the research site for over 800 feet. In other areas of tar sand development, it is expected that groundwaters will be present with the possibility for contamination.

As a result of the process, produced waters will exist. If the produced waters remain in the burnt-out tar sand zone, they should be monitored for migration and movement away from the retort area. Thus, a carefully planned groundwater monitoring and research program should be established to detect any migration or movement of this water away from the retorted area to determine means of preventing groundwater contamination. Similar types of studies should be run in the future on tar sands in situ retorting sites with groundwaters present near the tar sand beds.

Further fracturing research of tar sand beds to promote permeability may permit communication between water aquifers and the asphaltic sandstones. Subsequent processing will produce water that may contaminate aquifers. Produced oil and water are able to enter different aquifers because of the fracturing process. In addition, water may seep into retort areas and leach contaminants from the processed tar sands. This leachate is then transported into nearby aquifers. It is crucial that no aquifer be contaminated that may supply a nearby water well, or surface water.

Process water to be generated by reverse and forward combustion experiments at Asphalt Ridge represents a problem. For the 65 to 80 barrels of oil produced during experiment no. 1 at the research site, 120 to 150 barrels of water were produced. Although a large oil-to-water ratio may not be representative of a commercial process operating under steady state conditions, management of large volumes of water in an environmentally acceptable manner will be a factor which must be considered for commercialization of the process. Sites with aquifers in the vicinity of the retort area could be expected to produce more water than has been observed at Asphalt Ridge.

Process water has previously been disposed of by depositing it in liquid waste disposal areas of the local sanitary landfill. Small quantities have been used for characterization studies and research purposes. In a water-poor area, typical of many of the substantial deposits of tar sands, consumptive disposal of wastewater without reuse through the use of evaporation ponds would appear to be wasteful. In the future, produced water should be used for research in process water treatment and reuse schemes as part of the overall water management plan.

The goal of maximum water reuse should be pursued so that all water produced in retorting may be treated and put beneficially to use in research and commercial-scale operations.

Preliminary findings on the chemical nature of the retort water produced during experiment no. 1 at Asphalt Ridge have been presented by Barbour et al. (1976). These findings represent the results of a single study and utilized techniques which were designed to categorize the organic compounds present rather than to yield detailed information. The results should not be construed as necessarily being applicable to other sites. Indeed, changes in combustion could conceivably produce waters of a substantially different character.

Currently available information (Barbour et al., 1976) indicates that the inorganic material present to the greatest extent in retort waters are ammonium, sulfate, and chloride ions (Table III.B.1). Carbonates were virtually absent from the retort water examined, which is not surprising since the pH ranges from 2.5 to 4.0. Calcium, magnesium, sodium, and potassium were all found in low concentrations one year after the experiment wells were resampled and showed significant changes. The pH values had increased substantially and as a result significant quantities of bicarbonates were present. TDS levels were approximately the same as during the experiment. Calcium, magnesium, sodium, and potassium also were found in higher concentrations.

One ion of concern in the retort water is ammonium. When the water is withdrawn along with oil by production wells, the ammonium ion could be a benefit or a pollutant depending on the manner in which the water is managed. As a potent nutrient, ammonium ions could produce a serious

TABLE III.B.1 Water quality analysis for samples produced during reverse combustion of tar sands (concentration in parts per million)

	Sampling Time			
	1st Week	2nd Week	3rd Week	4th Week
Calcium	12	1.6	2.3	0.2
Magnesium	1.7	0.1	0.4	0
Sodium	1.2	0	0	0
Potassium	0.2	1.6	0.2	0
Carbonate	0	0	0	0
Bicarbonate	0	0	0	0
Sulfate	77	110	140	37
Chloride	8.8	60	170	60
Fluoride	11	6.0	4.0	2.1
Silica	54	1.5	0	1.6
Ammonium	140	790	72	41
Total Nitrogen	150	820	72	43
pH	2.7	4.0	2.5	2.7
Total Dissolved Solids	1,260	1,070	1,380	490
Chemical Oxygen Demand	42,000	29,000	38,000	39,000
Total Organic Carbon	12,150	7,970	11,230	11,595

pollution problem if allowed to reach surface waters. On the other hand, it might be beneficial used in revegetation efforts on the Asphalt Ridge site.

It should be pointed out that retort water is not likely to reach surface waters by accidental means, and plans to store the water on site

for treatment, reuse, and study should prevent surface water pollution. The Asphalt Ridge affords an excellent opportunity to study environmental problems associated with produced waters from this standpoint.

Levels of trace compounds and heavy metals as presently found in process waters are reported in Barbour et al. (1976). The toxicity of some of these compounds creates the potential for adverse effects to biota. The potential contaminants will require careful monitoring through observation wells at subsequent experimental sites during experiments. The extent to which those compounds travel with time from the process zone to surrounding areas could allow estimation of pollution hazards from commercial-scale operations, and give insight into chemical treatment schemes for minimizing the effects of these pollutants on downgradient waters.

A wide variety of organic compounds has been identified in the few process water samples which have been studied. Their behavior as aquatic contaminants is complex since many organic compounds are capable of undergoing interactions with inorganic contaminants, particularly metallic elements. These interactions may have synergistic or antagonistic influences on toxicity of either type of constituent. Without this type of information, the potential impacts of water quality changes due to retort waters cannot be properly evaluated. For these reasons, laboratory studies on pure compounds rather than whole process waters are of questionable scientific value to this application at this stage of tar sands development. Yet identification of known carcinogens or other toxicants present in produced waters is worthwhile. The entire area of environmental response to organics derived from in situ tar sands production will require an extensive research effort to be initiated with the research sites at the Asphalt Ridge.

Another problem that arises in dealing with organic pollutants related to tar sand is the difficulty of qualitative and quantitative analysis of organic contaminants. The results of organic analyses must be regarded as specific to a given site and should not be used to interpret events that may occur at other sites until correlative data are available. It is for this reason that retort waters from several sites within the research area should be collected and intensively examined to determine components which are potential contaminants.

A number of organic compounds have been identified in produced waters at the tar sands experimental site. These include phenol, cresol, and other compounds of potential toxicity to man. Acetic acid is abundant. The samples have not been completely characterized as yet, and this should be a prime objective for future experiments. A program to evaluate the toxicity of these organics should be considered a major goal. EPA standards formulated for drinking water under the Safe Drinking Water Act (PL 93-523) give particular attention to trace organics in drinking water. It is imperative that toxicity studies be completed to close the gap on the open issues of potential drinking water hazards from retort waters. It is not possible at present to evaluate the hazard involved, or indeed to determine if any exists. The research site at N.W. Asphalt Ridge can provide the process water for study to make possible a rational evaluation of the problem.

It must be pointed out that acute toxicity potential is better assessed from knowledge of peak toxicant burdens to be expected. Therefore, estimates of peak concentrations should also be sought and made available at each processing stage. Multiple water samples from each in situ experiment will be required to establish the range of both quantitative and qualitative variability in organic constituents.

Analysis of produced waters for more generalized measures of organic content are enlightening. Initial studies of waters from experiment #1 showed chemical oxygen demand (COD) values ranging 29,000 to 42,000 mg/l during reverse combustion. The COD test will not measure pyridine, some aromatics, and short-chain alcohols and fatty acids which may be present in the retort water. The COD, for example, of acetic acid will be considerably underestimated and thus the reported COD values may not be accurate. Based on limited data, it could be concluded that the retort water could have an adverse impact on surface waters if it should reach them. Samples taken from the combustion zone one year after the experiment at Asphalt Ridge was completed indicated that COD values were considerably reduced (over 90 percent) over levels found during combustion. However, COD's still ranged from 480 to 2080 mg/l, which are considerably higher than desirable from a potential environmental contamination standpoint. Groundwaters in petroleum production regions generally exhibit COD values well above those of "clean" water, yet lower than those found in this preliminary study. Data on the biochemical oxygen demand (BOD) are needed in order to assess the biological treatability of the organics present in the wastewater. Research should also be initiated to develop strains of organisms capable of attacking the complex organic mix in retort water biological treatment systems. The environmental impact of organic contaminants at the tar sand sites at Asphalt Ridge will be minimal, while produced waters are used principally for research and are not disposed of in a landfill without further investigation. The potential bioavailability of constituents in produced aqueous effluents should also be determined.

Disposal of process water is a serious problem in in situ retorting. Evaporation is one of the possible methods of disposal of the excess produced water. This would be done in evaporation ponds. These ponds could be adversely affected by incomplete oil-water separation efficiency.

Evaporation ponds would require a large land area in commercial-size operations. Sludges precipitated from process waters by evaporation would require studies in regard to their potential impact on subsequent land reclamation procedures when the ponds are no longer needed. Sludge treatment and disposal might be required.

The problems generated by evaporation ponds at research sites such as those at N.W. Asphalt Ridge would be small compared to commercial size operations. It would appear, however, that while evaporation should be examined as an alternative, the process water could possibly be put to better use. Several uses have already been pointed out (characterization studies, toxicity studies, etc.). One area of potential use for these research waters is in the development of alternative treatment methods which could be used in commercial operations to clean up and reuse the produced waters.

Under proposed EPA regulations (Fed. Reg., Aug. 31, 1976) it will be illegal to dispose of pollutants into wells where such disposal might contaminate a potential source of drinking water. The recommendation is that any underground source less than 10,000 mg/l TDS be protected. Consequently, underground injection does not appear to be a long-term viable solution for disposal of process water in all cases. However, the proposed regulations do allow the designation, through presentation of compelling evidence, of a particular aquifer as an unsuitable source of drinking water. Geographic areas where no underground drinking waters

exist may also be so designated, thus not requiring protection from contamination.

Disposing of water at landfill sites is a short-term solution. Waste disposal sites are required to maintain a liquids disposal area, where contamination to water will not occur.

Ideally, in an area where water is scarce, optimum management of the water resource would result in implementation of policies leading to maximizing reuse. A number of reuse possibilities exist, each requiring study to determine the degree of water treatment required to make a particular use of the retort water feasible. Tar sand sites near Asphalt Ridge would provide water to study this problem area. Preliminary samples indicate that the water is not satisfactory for irrigation without treatment. Boron concentrations were found to be above the 4 mg/l maximum recommended for irrigation of nonsensitive plants. Evaporation during irrigation would concentrate the remaining boron still further. Boron is not easily removed but selective ion exchange has had some success. The ion-exchange treatment also produces regenerant brines which would require disposal, perhaps by evaporation. Removal of organic constituents prior to use in irrigation might be required depending on their phytotoxicity. Feasibility studies of treating water for irrigation should be undertaken on the produced waters from tar sand research sites to determine: (1) treatment levels required, (2) optimum treatment schemes, and (3) cost involved in operating the treatment scheme.

Produced water could be used for cooling oily mists and vapors produced in tar sand retorting. Corrosive waters are generally unsuitable for this use due to pipe and cooling equipment corrosion. The low pH

of the produced water would indicate a very aggressive water which would require stabilization with pH adjustment, and this problem area requires study. Moderately high TDS waters such as retort waters usually cause scale deposition on cooling equipment, resulting in increased shutdown time and maintenance problems. Evaporative losses could be as high as 50 percent, which would mean that use of retort water for cooling would be saving a considerable quantity of water from other sources in the long term.

A commercial-scale tar sand oil production process will require a considerable amount of power for air compression, pollution control, and other needs which might necessitate on-site generation of power. Water requirements for steam generation could be substantial. The water may be cooled and recycled, but will show increased salinity with time. If cooling towers are used, salt buildup and slime growths may require chemical treatment which would alter the nature of the water. Cooling ponds are less expensive, but require a considerable amount of land area to be disturbed for an extended period. Salinity will also increase in cooling pond waters.

The direct discharge of thermally altered water to surface waters would have a deleterious influence on aquatic ecosystems and should not be practiced.

Boiler water for steam generation generally must be of the very highest quality, particularly for high-pressure boilers. It would appear that use of retort water for this purpose would require a very high degree of treatment due to high silica, TDS and low pH found in initial retort water samples from N.W. Asphalt Ridge. These results may not indicate the character of water from other sites, however. If the

concentration of the constituents in the preliminary samples is any indication of the levels that will be found elsewhere, the cost of treating boiler feed water could be prohibitive. This matter should receive close attention even though steam generation could require a considerable quantity of alternative water sources in commercial-scale operations.

Retort water would be suitable for dust control with only a sufficient degree of treatment to insure that toxic materials were not being disseminated into the environment. Such treatment might include adsorption of organics and heavy metal removal. This use would probably not require as much water as previously discussed uses and would therefore provide only a partial answer to achieving a zero water balance. Treatment required of water used in drilling would be similar to that for dust control.

Reverse combustion of tar sands during experiment #1 at N.W. Asphalt Ridge resulted in low oil recovery since permeability of the formation showed considerable heterogeneity. Only a portion of the Upper Rim Rock Tar Sands were consumed during the experiment. Subsequent experiments will use reverse combustion followed by forward combustion. Steam produced from treated retort water will be injected during a portion of these scheduled studies. This program must be carefully planned to avoid injection back into the formation of any volatile organics which might be harmful. This should not be a serious problem since the organics, being volatile, should either be consumed by the combustion process or returned to the surface with other volatile matter. This should be studied, however.

Investigation of combinations of these uses to provide an overall water management plan leading to zero water balance should be carried out in conjunction with the tar sand experiments being conducted in the Vernal area. The sites provide a suitable proving ground for development of this type of technology. Treatment needs, costs, and impacts will require clarification.

A portion of the produced water could be used as an aid for compaction of spent sand wastes from modified in situ and surface processing of tar sands. The leaching properties of the water should be thoroughly studied prior to widespread use for this application. For example, since they are basically granular, the spent tar sands are likely to be fairly permeable after oil extraction. The ability of spent tar sand to permit water to leach through it should be studied. Using produced water as a compaction aid would reduce the quantity of water to be ultimately disposed of. If this can be done in an environmentally sound manner, it should be encouraged. Treatment of the water for removal of organics, heavy metals, and other possible contaminants might be required.

While the experiments planned for the near future at Vernal are basically in situ combustion experiments with variations (e.g., reverse followed by forward combustion, reverse/forward combustion with fracturing), other experiments which may be carried out will present new environmental problems. A major area of planned technology development research focuses on the use of fluids to aid extraction of oil from the sands. Hot fluids, solvents, steam, and hot gases have all been proposed in the "DOE Tar Sands Program" as possible methodologies for use in in situ tar sands retorting. Steam injection into a formation would result in altered produced water quality compared to that observed

in preliminary studies of reverse combustion. Since much of the air injected into a formation passes beyond the retort zone, this might be expected to be true of injected steam also. It could increase leaching of minerals in the vicinity of the retort or carry petroleum-based organics beyond the burn zone. Solvents used in such experiments might not be completely recovered; thus their toxicity to humans, plants, and animals should be evaluated before injection so that should they reach a groundwater drinking water source or spring, the safety of the solvents will have been assured a priori. Monitoring wells should be installed and sampled frequently.

3. POST-OPERATIONAL PHASE

Following production at a site, the area should be restored to its original conditions as nearly as possible. After revegetation, the surface hydrological conditions should be nearly the same as those prior to development.

The post-operational impact of tar sand development on water quality consists of several effects. Short-term effects include those arising from revegetation efforts which may require up to 2 years of watering to achieve firmly established vegetation. Treatment of irrigation water to reduce boron may be required for a suitable supply if retort water from other operations or groundwater is used. The water, if drawn from surface supplies, will decrease streamflow available for waste dilution and waste assimilation and would be potentially harmful to stream biota. Little groundwater is available which is suitable for revegetation at the existing tar sand research site. This would necessitate use of surface water supplies, if rights could be obtained. Treated process

water will also be usable in commercial ventures when undesirable constituents are reduced to levels acceptable from a vegetation and pollution standpoint. Any water from irrigation of vegetation which is returned as surface water would have increased salinity due to soil leaching and evaporation and might require treatment to make it acceptable for discharge.

An additional short-term impact would arise from the use of nitrogen and phosphorus fertilizers in revegetation efforts. Many soils in tar sand regions are noted to be low in nitrogen and phosphorus and may require addition of these nutrients to achieve success in revegetation. Surface runoff from rainfall and snowmelt could carry nutrients derived from added fertilizers to surface waters or to adjacent undisturbed areas. The additional nutrients in undisturbed areas could result in stimulation of plant growth that could not be supported once the nutrient input ceased. A short-term disruption of the plant community could be the result. Data are lacking in this area and should be obtained for analysis.

Groundwater may intrude (where it occurs at a tar sands site) into the burned-out retort and gradually leach out hydrocarbons and combustion residues. Much of the oil present in the original formation remains as partially combusted oil or coke and could be leached if water is available. The increased rock surface area arising from fracturing processes will also enhance leaching of minerals from newly exposed sand. It is apparent that water will enter completed retorts, if water is available. It is also certain that some leaching will occur. It is not known to what extent leaching will occur or what its impact might be on the water resource, a problem which needs clarification.

Evaporation ponds have been proposed earlier as a means of wastewater disposal. This method has the advantage of being a "zero discharge" system, but will have both short-term and long-term post-operational environmental impacts. Evaporation will result in the deposition of precipitated salts. Actual quantities of salts would vary from site to site. The residue would concentrate heavy metals and organic or inorganic toxicants into a sludge deposit on the pond bottom. If the pond is covered with earth after the water has evaporated, a sludge layer would exist just below the surface which could leach pollutants for many years. Many of the pollutants present (e.g., boron) would be so-called conservative pollutants which do not decay in the environment and thus are available for leaching indefinitely. Lining evaporation ponds and cementing sludge deposits would prevent movement of any contaminants contained in the ponds.

Groundwater studies should continue for some years after the burn to determine communication problems between aquifers above and below the burned-out area. Long-term studies of leaching effects and fluid migration problems must be considered for near-term evaluations. These data will be required to determine if the retorted zones must be sealed, cemented, and/or isolated by other means from groundwater aquifers.

C. BIOLOGICAL

1. AQUATIC

a. Pre-Operational Phase

Problems such as dewatering or channelization are not foreseen for the in situ tar sands project near Vernal, Utah, as LERC has no plans for physical alteration of area streams or lakes. The site is arid and situated approximately 3.5 miles from the nearest perennial water source and 13 miles from the nearest downstream perennial water. Future projects located near perennial springs, streams, or lakes may require study to guarantee adequate water supplies or channel reclamation measures necessary to minimize harmful impacts.

Other pre-operational impacts at any in situ tar sands project will be principally short-term effects. The primary impact will be increased sediment deposition into aquatic habitats due to construction activities, equipment installation, and site preparation. Accidental gas, oil, or chemical spillage may occur, but will presumably be small in regard to consequences and simple to remedy since surface water is nonexistent near the site.

Adequate sediment containment during construction of sites by contouring to near-level surfaces, initiating settling basins for drilling operations to hold drilling mud, water, and debris on site, and revegetation will mitigate sediment loading of streams, thereby preventing degradation to aquatic habitats through erosion. Erosion control also localizes potential toxic material on-site. This is being carried out on the present site near Vernal.

Oil, gas, and chemical spills from construction, drilling, and fracturing activities represent potential toxic materials of the

pre-operational phase. Impact from these toxic materials will be small and localized on-site since the site is located in arid land and is only 6 acres in size. Impacts may be more consequential as research approaches commercialization.

b. Operational Phase

Adequate containment measures which have been undertaken at the Vernal tar sands site will mitigate sediment deposition into aquatic habitats during the operational phase. In addition, erosion is minimized by on-site activity which compacts soils, by a site location on arid land away from perennial and intermittent streams, and by the small size and levelness of the operational area.

Minor sources of pollutants such as air compressor engines, vehicle traffic, and flared gases at the present site are not considered to be adversely affecting aquatic habitats.

Toxic materials and salinity associated with the oil and water produced by the in situ process are considered to be primary factors which could affect the aquatic biota of area waters. Since contaminants are not released in the ongoing research and the site is arid, no significant impacts are expected. Preliminary research (Barbour et al., 1976) indicates that tar sands retort water contains lower concentrations of salt and less complex constituents of organic material than oil-shale retort water.

At the present LERC site, recovered oil and water are stored in tanks. The wastewater is ultimately disposed of in the liquid waste disposal area of a landfill dump or held for research. Water produced from the tar sands research site is not able to reach the distant aquatic habitats through surface water. Large-scale operations of the

future will require a disposal method more feasible for larger quantities of wastewater, such as water treatment for reuse or retention and evaporation to mitigate potential impacts upon aquatic habitats.

Production water from the Vernal site provides the opportunity to identify and study the components contained therein, while preventing access of these constituents to aquatic habitats. Preliminary work along these lines has begun (Barbour et al., 1976). Maximum permissible concentrations of constituents in tar sands process water must be established before release into aquatic habitats. Control technology to obtain these permissible levels should be obtainable (Barbour et al., 1976). Studies of the production water from the Vernal site should be helpful for the design of water treatment or access alternatives for disposal in mitigating the potential impact of toxic chemicals.

The problem of contamination of aquatic habitats from chemicals present in groundwater affiliated with in situ research is a suspected impact. Pathways may be opened for production and backflood water to water aquifers which may feed surface waters containing viable aquatic communities. These impacts are not expected to be significant on the small, arid, isolated Vernal site because of the distance to the Green River. Little is known about these impacts which will undoubtedly be important when the transfer of this technology to industry is accomplished.

Gases will be vented or flared at the experimental site and should have little potential for harming aquatic habitats. However, potentially hazardous trace materials which could be detrimental to aquatic habitats need to be identified and specific control measures proposed before large-scale in situ tar sands sites enter production.

c. Post-Operational Phase

Possible long- and short-term impacts during the post-operational phase include erosion and sediment deposition, gas escapement, and aquifer contamination. Proper revegetation and site reclamation will prevent excessive erosion and sediment deposition in aquatic habitats. Care should be taken to prevent gaseous escape during post-operational test boring. The present site is small, so impacts will be minimal.

Groundwater transport of toxic and saline materials from the underground retort site to surface aquatic habitats is the primary potential long-term impact during the post-operational phase. A primary research need is the identification of possible pathways and assessment of the probability of aquatic habitat contamination from this groundwater source. The arid land and isolation from perennial and intermittent water sources should effectively prevent contamination of lakes or streams by liquid effluent through the groundwater. However, measures to restrict the problem and aquatic studies to assess this impact should be undertaken. These studies are necessary for identifying site-specific impacts and for developing technical expertise that can be transferred to industry should LERC research trigger the commercialization by industry.

2. VEGETATION

a. Pre-Operational Phase

Impacts and Risks

Potential impacts and risks associated with vegetation in the construction phase of true in situ processing of tar sands include:

1. Removal of land from present use.
2. Effect of clearing vegetation on later land use.
3. Soil loss from erosion caused by vegetation removal.
4. Soil loss due to tar sand disposal.
5. Soil contamination with toxic chemicals.
6. Effects of heating soil.
7. Loss of vegetation by removal.
8. Loss of vegetation from toxic chemicals.
9. Loss of vegetation from tar sand disposal.
10. Loss of endangered species.
11. Loss of vegetation by a change in water quality or quantity.

(1) The major use of the semi-arid land near Vernal, Utah, is for grazing domestic livestock and for wildlife year-round. Limited acreage is eliminated for grazing purposes at the present time with past and on-going true in situ experiments. However, this represents a very small part of the region and is not significant in comparison to the area available in that no critical habitat is destroyed. Actions which occur to change land use include building and upgrading access roads, installing power lines, constructing buildings, clearing and contouring sites for drilling wells, and installing equipment. Methods utilized to accomplish the above include scraping and leveling vegetation and soil surface by bulldozer. The area affected is four acres. These actions cannot be avoided with the development of in situ processing of tar sands.

(2) Scraping the vegetation and soil surface to level and contour the site for development of tar sands will destroy the existing vegetation. Consequently, production for grazing will be lost. Revegetation

of affected lands will be carried out. However, native stands of existing shrubs will take time to again become established as food for livestock grazing. As shrubs become available, past and present use will be restored. This impact is not significant in that the area disturbed is only four acres of shrubland characteristic to the region south of Vernal. No critical habitat is manipulated. Topsoil has been stockpiled. This action cannot be avoided.

(3) Soil loss from erosion caused by removing the vegetation will be minimal in that the present research site is located in a relatively flat area. In addition, because of the nature of the actions to be carried out, level surfaces are needed with the exception of access roads. Soil loss should be at a minimum due to compaction, graveling, and limited space needed for site preparation. This action can be and is presently minimized by correct management.

(4) Soil loss due to disposal of tar sands will not be an impact encountered with the present true in situ techniques since tar sands are retorted in place. Surface or modified in situ experiments will require stockpiling raw or retorted tar sands and overburden. If these experimental procedures become viable research projects, the removal and stockpiling of topsoil will help mitigate soil loss for revegetation purposes and help reclaim the area after the project is completed.

Impact from stockpiling. No immediate effect from stockpiling will occur from mined and retorted tar sands with true in situ experiments in that all sands are left in place underground. Stockpiling will have impacts if future surface and modified in situ studies take place.

(5) Soil contamination with toxic chemicals during the construction phase would most likely occur from oil and gas spills from equipment

used to prepare the site. In addition, spills from chemicals used in fracturing and drilling could have toxic effects. Again, the research area is small, and is located in a common shrub community. Any accidental spill would be localized to the immediate area and limited in size. This is not expected to be a significant impact and is one which cannot be avoided when using mechanized construction equipment.

(6) The effect of heating soils near the soil surface has not been observed since LERC, in past experiments, has not detected changes in temperature near the surface during processing.

(7) The loss of vegetation by removal has been and will be the major visible impact encountered in true in situ recovery of tar sands. The impact occurs during the construction phase. The dominant vegetation consists of shrubs which take time to become established. Once the scraping has occurred, the sites are barren and support only limited grass species and annual forbs. As development and activity increase around the site, soil compaction further eliminates plant growth. This action cannot be avoided and will not be significant in that only four acres of shrubland will be manipulated. Shrubs removed are characteristic of the Vernal area and are representative of those covering large areas around the proposed site.

(8) The loss of vegetation from toxic chemicals will most likely not occur during the construction phase. Scraping and compaction are the major actions for the removal of vegetation.

(9) Loss of vegetation from tar sand disposal will not be an impact of the true in situ techniques, since tar sands are retorted in place.

(10) Loss of endangered species is not expected to occur at the present time since none have been found to exist in the general area or on the specific site.

(11) The loss of vegetation by a change in water quality or quantity is not expected to occur since the study area is arid. Only accidental spills from water used in drilling and fracturing could escape to vegetation offsite. This is not likely to occur. Waters used for both actions are contained in pits for reuse and then evaporated after operations cease.

Potential Cumulative and Long-Term Effects

The critical cumulative and long-term effects associated with the construction phase are those affiliated with surface disturbances. Damaged shrublands will take time to again reach their previous state of existence through revegetation programs and invasion from surrounding plant communities. Invading and planted grass and forb species in the meantime will give the disturbed sites a grassland appearance. Although shrublands will be eliminated temporarily as feed for livestock, the diversity of grass and forb species planted will enhance the overall diversity of habitats for wildlife in an area where shrubs are the dominant vegetation type. The long-term effect is not expected to be significant in that the area disturbed is four acres and is located in shrublands common to the surrounding region.

Natural succession of the surface disturbances without vegetation programs will progress from a surface compacted and eroded by wind and water to a mixture of annuals dominated by the following species: Lambsquarter goosefoot (Chenopodium album), Barilla (Halogeton glomeratus), Greenmolly summercypress (Kochia americana), Common Russian thistle

(Salsola kali), Western tansymustard (Descurainia incisa), Pinnate tansymustard (D. pinnata), Flixweed tansymustard (D. sophia), Field pennycress (Thlaspi arvensis), and Cheatgrass brome (Bromus tectorum).

Grasses and a mixture of perennial forbs will then start to invade, along with scattered shrub seedlings. Bottlebrush squirreltail (Sitanion hystrix), Indian ricegrass (Oryzopsis hymenoides), and Western wheatgrass (Agropyron smithii) will be the dominant grasses. Needle-and-thread (Stipa comata), Bluebunch wheatgrass (Agropyron spicatum), Galleta hiliaria (Hilaria jamesii), and Big sagebrush (Artemisia tridentata) will show up as seedling shrubs. The annual species will still exist as the dominant vegetation community, but over time will eventually be out-competed by the perennial grass and forb species.

Mitigating Measures

Alternative actions in respect to vegetation during the constructive phase are as follows:

1. No action.
2. Conducting research on true in situ processing with or without initiating a progressive reclamation program.
3. Conducting research with or without a vegetation monitoring program.
4. Initiating a reclamation program after all research is completed.
5. Initiating a reclamation program on individual sites immediately after research is completed.

(1) No action is not a feasible or desirable alternative in that DOE-LERC is charged with investigating the feasibility of utilizing true in situ techniques for processing tar sands.

(2) Conducting research on true in situ processing without a progressive reclamation program is not a feasible alternative. Federal and state laws require reclamation of mining sites to an equal or better condition than existed before mining took place. Reclamation of disturbed sites must take place.

(3) Conducting a reclamation program without a vegetation monitoring program depends on restoration of plant species adapted to environmental conditions and surface rehabilitation. Monitoring is required both before and after the disturbance to insure and evaluate success.

(4 and 5) Conducting a reclamation program after all research is completed is a viable alternative. However, undesirable annual plant species will become established. These plants will then compete with desirable plant species at a later date when reclamation takes place. Rehabilitation of native range will be set back by a period equal to or longer than the time taken to conduct in situ research. Realizing ERDA's goal of eventually reaching the pilot-plant stage and then commercialization of tar sand processing, research on the success of revegetating lands subjected to less than 10 inches of moisture should be carried out as soon as possible. It is, therefore, realistic to consider rejecting this alternative and to initiate a reclamation program on individual sites immediately after research is completed. Doing so will keep the acreage of disturbed land at a minimum and update successful reclamation research.

Overall, the construction-phase impact on vegetation from tar sands research utilizing true in situ techniques is minimal at the present scale of operation. Expanded programs using true in situ processing and research on modified in situ technology or surface mining will necessi-

tate initiating basic inventories of plant life and monitoring programs for measuring the success or failure of reclamation programs.

Initiating a reclamation monitoring program on sites abandoned within the four-acre research study area utilizing successful research techniques in the oil-shale lease programs, Utah A and B and Colorado A and B will enable the progressive development of tar sand technology as well as alleviating the questions of reclamation at disturbed sites.

Summary

The major impact on vegetation during construction will be surface disturbance and removal of vegetation. Shrubs characteristic to the arid lands within the Vernal area and utilized by livestock and wildlife for grazing will be lost for a lengthy time after reclamation. No critical habitat will be lost. Topsoils are presently being stockpiled for reclamation purposes. The impact site will be minimal for research operations. Four acres and approximately 2 AUM's will be lost for grazing until reclamation takes place. Reclamation and monitoring programs will be initiated to revegetate each site as research is completed. Information gained through these programs will be utilized for updating reclamation of arid lands and in preparation for pilot and commercial-scale operations.

b. Operational Phase

Impacts and Risks

Short-term impacts and risks associated with in situ development of tar sands during the operation phase include:

1. Removal of land from present use.
2. Effect of clearing vegetation on later land use.
3. Soil loss from erosion caused by vegetation removal.

4. Soil loss due to tar sand disposal.
5. Soil contamination with toxic chemicals.
6. Effects of heating soil.
7. Loss of vegetation by removal.
8. Loss of vegetation from toxic chemicals.
9. Loss of vegetation from tar sand disposal.
10. Loss of endangered species.
11. Effect of plant emissions on land use.
12. Change in air quality.
13. Loss of vegetation by a change in water quality or quantity.

Numbers 1, 2, 3, 4, 6, 7, 9, and 10 will not change from the previous discussion of construction-phase effects on vegetation. However, the effects of plant emissions on land use (11) and changes in air quality (12) have not been determined. Although limited monitoring programs have been carried out with in situ processing and the gases given off, their effects on vegetation have not been addressed. They are not expected to have a significant effect at the present scale of operation in that they are oxidized and flared to carbon dioxide and limited sulphur and nitrogen gases.

Soil contamination (5) and loss of vegetation (8) from toxic chemicals represent critical risks during the operating phase of in situ processing. Contaminated soils could eventually be in contact with plants through revegetation programs, accidental spills, and in the surface disposal of retort-produced, ground, and backflood water. If future modified in situ and surface mining research takes place, chemicals and salts leached from disposal piles could affect vegetation. Consequently, toxic chemicals represent a potential for cumulative and long-term effects on vegetation.

(13) The risk of adverse impacts from toxic chemicals cannot be avoided in true in situ or modified in situ technologies. Fracturing, burn ignition, the retort burn, and gas and liquid injection all have

the potential of changing the quality and quantity of the water affiliated with the oil that is produced underground by the burn. Effects on soils and contact by plants of in situ produced water without treatment is not known at this time. The effects of leaching from oil-shale disposal piles and programs for revegetation have been and are being studied in connection with oil-shale programs in Colorado and Utah (U.S. Department of the Interior, 1973; VTN, 1976). The research may be helpful in addressing the leaching of tar sand disposal piles if surface and modified in situ operations take place in future research.

Impact on vegetation of a change in water quality or quantity is not expected to be significant with LERC's research efforts. The scale of operation is small and all produced water is contained in tanks and lined pits. Accidental spills could occur from tanks. However, the containment provided is to hold twice the total quantity of the tanks themselves. LERC has initially characterized the constituents of the water recovered from a true in situ burn (LERC, 1974). Constituents listed reveal that the water could be toxic to biological systems without treatment. Consequently, LERC has developed and proposed a program to monitor the biochemical and bioenvironmental interactions of aqueous effluents from the in situ processing of fossilized fuels. The study of soil transport, interactions within the soil, and phytotoxic effects are included within this proposed program. The arid, isolated Vernal research site offers an excellent opportunity for studying in situ produced waters for possible contamination of the biosphere in that produced water is contained and present in amounts conducive to controlled laboratory and field research on cold desert shrublands.

Mitigating Measures

Alternative actions during the operating phase are as follows:

1. No action.
2. Impoundment of produced water.
3. Treatment of produced water and use thereafter.
4. Initiation of a monitoring program.

(1) No action is not a viable alternative in that ERDA-LERC is charged with the investigation of in situ processing of tar sands. In order to fulfill this mission, retorting must take place.

(2) Impoundment of produced water in storage tanks is taking place at the present time on the Vernal site. Impact on vegetation from retort-produced waters is therefore not occurring. As excess water is produced, the water is transported by tanker trucks to municipal dumps and deposited in a liquid disposal area. Although the problem of produced water can be confined to storage tanks at the present level of research, pilot-plant and commercial-scale operations will produce quantities which could cover extensive areas of land and consequently affect the vegetation thereof.

(3) Treatment and subsequent use of produced water is a viable goal to reach before the pilot scale and commercial in situ retorting of tar sands becomes a reality. Detailed results from revegetation research programs will enable control technology design alternatives for water treatment if so desired for eliminating chemicals toxic to vegetation. In turn, plant species may be found which could be utilized for tertiary treatment by uptake and bioaccumulation of chemical fractions within the produced water.

(4) An initial monitoring program for the effects on vegetation from toxic water produced by in situ processing during the research phase

represents a means to substantiate and help mitigate impact on the native flora. Monitoring composite samples from future burns will help verify characteristic constituents occurring in retort-produced water and stabilize research goals for depicting vegetational response to produced water.

Summary

The critical impact on vegetation during the operating phase will arise from chemicals produced by in situ retorting of tar sands. The significance of the potential toxins is not known at this time. It is expected that in situ produced water will be toxic to plants and to other organisms in the soil. In situ water is produced and contained in quantities conducive to laboratory and field research within the dry and isolated site near Vernal. This water offers a first-time opportunity to study its toxic effects on the biosphere by utilizing a small research project to predict the impact of pilot and commercial-scale endeavors.

c. Post-Operational Phase

Short-term impacts and risks associated with in situ development of oil shale during the post-operation phase include:

1. Surface disturbances from the removal of equipment.
2. Abandoned roads.

Surface disturbances from the removal of equipment and facilities will be minimal, as will the effects of abandoned roads on vegetation. Site preparation during the construction phase will have removed the native flora. Only those plants invading the scraped and compacted surface near the facilities and those growing in the roadbed are subject

to destruction. Annual species described earlier will be the dominant plants. These species are undesirable for revegetation and will be eliminated during mechanical treatment of the post-construction surface disturbances for seedbed preparation. No doubt they will again occur in association with the seeded species chosen for reclaiming the site.

3. TERRESTRIAL FAUNA

a. Pre-Operational Phase

Short-term impacts and risks associated with in situ processing of tar sands include increased noise, traffic, and human activity. In addition, fugitive dust may lower air quality and cause wildlife to abandon undisturbed habitat around the site. Water contaminated by oil spills and the dumping of toxic materials into water supplies could cause a deterioration of habitat quality or animal losses. As roads are built, access is increased, which increases the possibility of animal losses through collisions with vehicles or indiscriminate shooting.

The short-term impacts of noise, traffic, and human activity on the Vernal site will be slight due to the small operation. Only one or two acres will be cleared for each experiment. The 0.7 mile of existing trail can be graded and improved to allow all-weather traffic. Dust created by construction and clearing of the site should not be enough to affect air quality. Oil spills will occur sporadically from equipment on site but will be localized and are not expected to create a significant impact. The increase in traffic during the experimental operation will be small and losses of wildlife through collisions and indiscriminate shooting are expected to be slight.

The most important long-term effect of any type of development on the local wildlife is the loss of habitat. The seriousness of the impact will depend on the quantity of habitat, the quality of the habitat, and the fauna disturbed. Large mobile species such as Coyotes or Mule Deer can move away from the area while smaller, more restricted species such as the Sagebrush vole will be lost. Poorly placed developments could disturb intensive usage areas or migration routes of wild animals.

The site near Vernal is less than 10 acres and this small loss of habitat should have little effect on wildlife of the area. Small rodents that have home ranges restricted to the site will be lost, while larger mobile species will move away. The vast area of sagebrush habitat will allow the displaced animals to relocate without a great deal of stress or competition with those animals already living in the off-site areas. This small experimental development will not disrupt intensive use areas or migration routes.

Mitigating measures include the following:

1. When clearing the site and building roads, as little of the area surrounding the site should be disturbed as possible.
2. Roads on the site should be watered to retard dust if problems occur.
3. When construction is completed, any disturbed areas not needed for operations should be reclaimed.
4. Roads that are not needed for operations should be closed to traffic and reclaimed.
5. When reclaiming disturbed sites, native species of shrubs and grasses should be used to aid in rapid restoration of natural communities.
6. Educational programs should be designed to aid in preventing wildlife losses through thoughtless acts of the construction workers.
7. Habitat improvement programs should be initiated if the site is determined to be located in an intensive usage area such as a winter range for big game animals.
8. If larger sites are used in the future, and if migration routes exist through or near the sites, corridors should be left to allow free movement of wildlife.

In experimental operations such as those proposed by ERDA-LERC, where only small portions of land are needed for each operation, habitat disturbance can be held to a minimum. As an experiment is completed and a new site is being cleared, the abandoned site should be reclaimed.

This process would speed the return of the area to its natural state.

b. Operational Phase

The short-term impacts of the operational phase would be much the same as those of the construction phase. The impacts of traffic, noise, and dust would still be present. Indiscriminate killing of animals and collisions with vehicles could still be a problem. Oil spills and improper handling of toxic materials could cause impacts on local populations.

Long-term effects would be a loss of habitat and the disruption of animal activities for the duration of the operation.

Releasing toxic gases into the air could cause cumulative buildup of materials in the tissues of plants and animals and this could have a long-term effect on the environment. If the natural flow of groundwater is blocked during the process, springs would stop flowing and an important use area for wildlife would be lost. Toxic materials released into the groundwater could contaminate areas miles from the site.

A dump will be required for cuttings from the drill holes. This dumping area will present additional loss of habitat.

The impacts of traffic, noise, and dust at the Vernal site should be slight due to the small scale of the operations.

The short-term nature of the experimental operations, 2 to 5 years, and a well-planned revegetation program should prevent long-term loss of habitat. Each experiment only requires 1 or 2 acres and as an experimental plot is abandoned, it should be reclaimed to speed recovery of the lost habitat.

Some air pollution of a temporary nature would result from vented combustion products of produced gas, but the gases vented would comply with state and federal air quality control standards.

Groundwater supplies should not be affected by the experiments since after testing, no groundwater has been found.

Tailings from the drill holes should not be of great importance in this limited operation. They could be disposed of by spreading them out over open areas. In larger operations, where disposal dumps would need to be large, the cuttings should be located where leaching or sediment from erosion would not contaminate water supplies. The dumps should be revegetated with native vegetation wherever possible.

Mitigating measures include the following:

1. Roads should be watered to retard dust if problems occur.
2. Traffic should be restricted to the main roads to prevent further disturbance of the environment.
3. Roads not needed in the operation should be closed and reclaimed.
4. Information and education programs for the employees should be designed to aid in conserving wildlife resources around the site.
5. In large commercial operations, state and federal conservation officers should be allowed ready access to the property to aid in prevention of wildlife losses due to careless acts of employees or unsatisfactory operations.
6. Fuel and oil storage facilities should be fenced to prevent wildlife from coming in contact with these substances. They should be surrounded by earthen dikes which have greater volumetric capacities than the tanks, to contain any accidental spills.
7. Habitat improvement programs should be initiated if the site is determined to be located in an intensive usage area. If migration routes are blocked, corridors should be left either through or around the site to allow free movement of wildlife.

c. Post-Operational Phase

Short-term impacts will diminish as operations cease. Long-term impacts, such as loss of habitat, will take time to be negated. Even with revegetation, time will be required for the site to become a stable vegetative community again. It would aid the return of the area to its climax vegetation type if native species of shrubs and grasses suited for the local conditions are used. As the disturbed area returns to its native vegetation type, wildlife usage will increase.

Effects from possible air pollution would diminish after production is halted. There could be lingering effects seen in those plants and animals affected during production.

If groundwater systems were disturbed during the operations they could remain in the disturbed state long after production has ceased.

D. AESTHETIC, RECREATIONAL, AND CULTURAL

1. POTENTIAL CULTURAL IMPACTS

Short-term direct impacts on cultural resources will not be present as no sites were found in an intensive inventory of the experimental site. A small increase in population in the Vernal area would occur during project development. This population increase could accelerate the continual erosion of cultural resources as a result of artifact collecting.

Long-term impacts to cultural resources could be felt as a result of expansion of in situ recovery from tar sands. If a large acreage were drilled for tar sand production, archaeological and historic sites could potentially be destroyed. The vicinity of the tar sands pilot project is identified as one of generally moderate to high moderate archaeological site density. Therefore the probability is high that some cultural sites could be adversely affected by the expansion of the proposed action.

2. PROCEDURES FOR MINIMIZING IMPACT

If the tar sands project is expanded beyond the pilot phase, archaeologists should be called in to survey all areas of contemplated surface disturbance well in advance of development. If archaeological or historic sites are discovered, plans can then be made either to preserve the sites or to excavate and record the data contained therein. If adequate time and funding is provided for studying sites that may be found in areas of project expansion, the impact on these sites can be minimized or mitigated.

E. SOCIOECONOMIC ENVIRONMENT

1. PRE-OPERATIONAL PHASE

Because the tar sands project was initiated in 1974 the site construction has already taken place. Socioeconomic impacts would be insignificant with such a small project being constructed. This is especially the case for a town with a sizable tourist trade where there are numerous motels and restaurants for the LERC personnel to use when working at the tar sands site. Many people in Vernal seem completely unaware of the existence of the project, although there is a sign on Highway 121 indicating the location of the site.

2. OPERATIONAL PHASE

It has been estimated (Bureau of Mines, 1974:21) that project personnel would range from 8 to 12 men, although more recent LERC estimates range from 6 to 20 men. Using the range of 6 to 20 workers, we do not predict any perceptible socioeconomic impacts on Vernal and the surrounding area. Twenty additional people in the area would go virtually unnoticed.

3. POST-OPERATIONAL PHASE

We expect the greatest amount of socioeconomic impact to come with population increases. Since the tar sands site operates with such a small number of people (6-20), we do not expect any significant impacts upon their leaving the area. However, if an in situ technology

is developed so that commercialization becomes feasible, we expect increase in employment associated with tar sands to rise to significant levels.

4. COMMERCIALIZATION

The very open question of commercialization involves many different variables. Current oil reserves in tar sands are believed to be around 29 billion barrels (in the U.S.).

True in situ tar sands technology still appears to be in an embryonic stage. It is difficult at present to make predictions concerning the future of tar sands especially as related to true in situ extraction methods. No employment figures can be projected for a commercialized in situ tar sands site because the technology is not sufficiently advanced at present. Therefore, as the technology becomes more advanced emphasis should be placed on labor demands for commercial operations.

At present the only available labor statistics concerning tar sands commercialization are from The Utah Process, Alternative Futures, 1975-1990 (Utah State Planning Coordinator, 1975). These statistics represent the number of mining employees necessary to surface mine tar sands in the Uintah Basin. The estimates are:

1980 - 30 Mining Employees

1985 - 90 Mining Employees

1990 - 90 Mining Employees

The following population/employment figures were computed using an Economic Base Model that uses ratios of basic employment to total employment and total employment to population. Basic employees are defined as those involved with construction, mining, or manufacturing.

These employees are responsible for bringing outside money into the community by exporting goods and services outside the area's boundaries or by being paid by persons or organizations located outside the area.

The ratio for basic employment to total employment for Uintah County is estimated at 1:1.8 (Logan et al., 1976:34). The ratio for total employment to population was obtained by averaging employment to population ratios for all "alternative futures" (0 to 10) from 1980 to 1990 as established by the computer simulation models developed as the Utah Process (1975). This employment to population ratio is 1:2.37.

Using these multipliers, an increase of 30 basic employees in 1980 due to surface mining of tar sands would mean a concomitant population increase totaling 128 people. An increase in basic employees to 90 in 1985 and 1990 would mean a population increase of 384 persons. This population increase would be the direct impact of tar sands surface mining in the area. Table III.E.1 indicates the changes in population and employment that would be brought about by surfacing mining of tar sands in Uintah Basin. These figures are based on the revised population figures for the Uintah Basin, which includes Duchesne, Daggett, and Uintah Counties. The N.W. Asphalt Ridge Tar Sands site is located in Uintah County, however. Table III.E.1 makes use of "Future Zero" of the Utah Process (1976 Revision), for projected baseline populations. The projected population losses for this "Future," however, are not realistic; the situation in this mineral-rich area of Utah is dynamic rather than static. These baseline projections may therefore be misleading.

TABLE III.E.1. Population and employment projections with and without tar sands, 1980-1990

"Future 0" Projections	1980		1985		1990	
	Employment	Population	Employment	Population	Employment	Population
Uintah Basin	14,501	34,490	14,248	33,545	14,866	31,609
Tar Sands Surface Mining Projections for Uintah Basin	30	128	90	384	90	384
"Future 0" and Tar Sands Development for Uintah Basin	14,531	34,618	14,338	33,929	14,950	32,093

Source: Utah State Planning Coordinator, 1975.

It must be reiterated that the figures in the table represent only surface mining of tar sands. This type of recovery is inefficient and thus not applicable where tar sands are located in deep strata.

In situ technology has not reached the stage of development to serve as a basis for firm employment projections. What must be considered are the recent developments in the area of oil shale. With oil shale becoming a commercial reality in the region, we could expect commercial development of that resource in the Uintah Basin. Because the multi-county district approach of the Utah Process does not correspond to the same set of counties studied by Western Environmental Associates Inc., absolute comparison of population projections is difficult. It is important to point out, however, that development of tar sands is likely to come after development of oil shale in the Uintah Basin. Therefore, population increases due to tar sands commercialization will be in addition to those brought on by development of oil shale.

As the tar sands technology becomes sufficiently advanced to make employment projections possible, comprehensive work should be carried out to compute the compound population increases that would be initiated by oil shale and tar sands commercialization. The Department of Sociology at the University of Wyoming has developed a simple simulation model which has the capacity to project total population, housing need by type, school population by grade levels, and revenues and expenditures at the city or county level given exogenous employment. Thus, given present employment and expected employment for new energy development(s), the model can produce reliable projections for the above variables for the various levels of government. Because of the importance of basic employment in an economic base population projection model we recommend

attention be concentrated on accurately predicting necessary employment for new technologies operating at the commercial level.

F. OCCUPATIONAL HEALTH AND SAFETY

Occupational health and safety and human health considerations research relating to tar sands in situ processing has not yet been started by LERC. Some of the potential health and safety impacts that may be found during in situ processing of a resource (as well as other technologies) are as follows:

1. exposure to abnormalities of temperature, pressure, shock, and vibration;
2. exposure to climatic extremes, naturally occurring dusts, insects, noxious weeds, and sunlight;
3. exposure to gaseous products containing complex organic compounds through leaks and emissions;
4. exposure to high levels of noise, high-temperature equipment, and corrosive materials; and
5. exposure to mutagenic and toxic liquids through handling and research.

Site and research laboratory personnel will be involved with the handling of aqueous effluents during and after the TS-2 experiment, which is ongoing (October, 1977). The effects of potential exposure through accidental ingestion or contact must be determined in order to prescribe appropriate safety precautions. It is possible for LERC, depending upon adequate funding, to determine the acute toxic effects of exposure to aqueous effluents produced in the course of the Vernal site projects. Acute studies include skin, eye and respiratory irritation, skin sensitization, acute dermal LD-50, aspiration toxicity, acute oral LD-50 in 3 species, and sub-acute 90-day oral toxicity in rats. Mutagenicity screening studies could also be undertaken.

The physical hazards, such as exposure to temperature, pressure, vibration and noise, are mainly of a general industrial nature, occurring

within the site and largely confined to the work force. LERC complies with OSHA standards and conducts its research in accordance with standard oil field safety practices.

CHAPTER IV

COORDINATION WITH FEDERAL, STATE, AND LOCAL PLANS

Prior to 1960, tar sands was a locatable mineral. By that, it is meant that a person could locate a mineral deposit, perform annual assessment work, and eventually receive a patent.

The Mineral Leasing Act of February 25, 1920, effected a complete change of policy with regard to the disposition of lands containing deposits of coal, phosphate, sodium, oil, oil shale, and gas. Thereafter, such lands were no longer to be open to location and acquisition of title, but only to leasing. In express terms, section 37 of the Act (30 U.S.C. 193) directed that deposits of these designated minerals in lands valuable therefore should be subject to disposition only as provided in the act, namely, by leasing; but it made an exception as follows:

except as to valid claims existent at date of the passage of this Act and thereafter maintained in compliance with the laws under which initiated, which claims may be perfected under such laws, including discovery.

By enacting the Mineral Leasing Act Revision of 1960, Congress added tar sands to the list of leasable minerals. It came to the attention of Congress that

tar or petroleum sands [were] locatable under the "Mineral Law of 1872," with the locator getting outright ownership of all of the minerals without royalty or rent to the Federal Government, and consequent increase in State revenues. Evidence was presented to [Congress] showing that the . . . bill would open the way to the recovery of many billions of barrels of oil from such sands and thus give the United States a vast new reserve of petroleum within our own borders so vital to our national security and economic development. (1960, U.S. Code Congressional and Administrative News, p. 3313.)

The Mineral Leasing Act then was changed to read, in part, as follows:

The Secretary of the Interior is hereby authorized to lease to any person or corporation . . . any deposits of oil shale, native asphalt, solid and semisolid bitumen, and bituminous rock (including oil-impregnated rock or sands from which oil is recoverable only by special treatment after the deposit is mined or quarried) belonging to the United States and the surface of so much of the public lands containing such deposits. (30 U.S.C. 241.)

Congress anticipated two problems when they passed this legislation: (1) that persons would be attempting to locate on and patent tar sands under the mining laws, and (2) that tar sands would be interspersed with other minerals. The first problem was addressed in 30 U.S.C. 241(b):

If an offer for a lease under the provisions of this section for deposits other than oil shale is based upon a mineral location, the validity of which might be questioned because the claim was based on a placer location rather than on a lode location, or vice versa, the offeror shall have a preference right to a lease if the offer is filed not more than one year after September 2, 1960.

Congress intended that lands containing tar sands also be available for leasing of all other "leasing act minerals."

With respect to native asphalt, solid and semisolid bitumen, and bituminous rock (including oil-impregnated rock or sands from which oil is recoverable only by special treatment after the deposits are mined or quarried) a lease under the multiple use principle may issue notwithstanding the existence of an outstanding lease issued under any other provision of this chapter. (30 U.S.C. 241(c).)

Tar sands, then, may be held under two different pieces of legislation, the Mineral Law of 1872, under which "tar sands was a locatable mineral," or the Mineral Leasing Act Revision of 1960. Consequently, some lands which were once federal are now owned in fee by successful locators, while others are subject to leasing.

Now, "leases or permits may be issued only with the consent of the head or other appropriate official of the executive department . . .

having jurisdiction over the lands containing the deposits" (43 CFR 3501.2-6). More specifically, according to the Tar Sands Task Group of the National Petroleum Council, the substantial Utah deposits are the most likely to be exploited among all known deposits in the United States. The force report cited several problems which may delay significant production in the state of Utah, for example:

1. The Tar Sand Triangle and Circle Cliffs giant deposits are largely on Federal lands. Leasing of Federal lands for "asphaltic minerals" or tar sands have been delayed pending legislation.
2. Proposals for national parks, national monuments, desert wilderness areas and recreation areas cover most of the Circle Cliffs and Tar Sand Triangle giant deposits and could result in surface uses incompatible with mineral resource development.
3. Tar sands and oil shale are superimposed in the P.R. Springs giant deposit, which may present legal difficulties.

Commercialization of a tar sands research program is contingent upon the solution of legal problems that must be resolved in order for industry to become involved.

Some of the primary factors which limit the growth of a tar sands industry in the United States include:

1. Lack of a clearly defined national tar sands policy as part of a broader national energy plan;
2. Lack of a clearly defined and workable tar sands leasing policy.
3. Lack of a firm and definite policy regarding a subsidy or guaranteed price for the development of the synthetic fuels industry in the United States.
4. Lack of information on the exact nature and the extent of domestic tar sands deposits. ("Energy from U.S. and Canadian Tar Sands: Technical, Environmental, Economic, Legislative, and Policy Aspects," Report Prepared for the Subcommittee on Energy of the Committee on Science and Astronautics, U.S. House of Representatives, 93rd Congress, 2nd Session, December 1974.)

Constraints on leasing. Potential conflicts exist between lessees of oil and gas and lessees of bituminous sands. For example, the bituminous sands lessee can mine the tar sands and extract the oil from

them, but does he have legal ownership of the oil if he extracts the oil from the sands by an in situ (in place) processing method? The major problem is to resolve the question of who has the right to which material when the hydrocarbons are extracted from the ground by in situ processes. This conflict arises from the language in 30 U.S.C. 241, which reads:

The Secretary of the Interior is hereby authorized to lease to any person or corporation . . . any deposits of bituminous rock (including oil-impregnated rock or sands from which oil is recoverable only by special treatment after the deposit is mined or quarried) . . .

Does ownership of the oil belong to the conventional oil and gas lessee, who has traditionally been able to introduce pressure maintenance, fire flooding, or other methods to increase recovery from an oil well? This problem must be presented to the Interior Department and Congress for solution.

NEPA Compliance

NEPA, in conjunction with DOE's own NEPA compliance guidelines, makes the preparation of EIA's and EIS's an integral part of its environmental requirements. The procedure for preparing these documents is presented in 10 CFR 71. LERC is complying with the NEPA and DOE mandates in preparing these documents.

Water Assessment

Section 13 of the Federal Non-Nuclear R & D Act calls for three types of water assessments aimed at programmatic or regional effects, demo plant impacts, and commercial plant impacts in subsections (a), (b), and (c), respectively. Section 13(a) programmatic assessments are carried out by the Water Resources Council (WRC) at DOE's request.

Section 13(b) is the sole responsibility of DOE. WRC prepares the 13(c) commercial plant assessments. None of the above are applicable to LERC projects until they reach the demo plant stage.

Environmental Quality and Monitoring

LERC will comply with all Federal and State environmental quality regulations on all field projects. LERC will continue to be in contact with state and local planners to assure that technology development will not create any surprises to local communities.

CHAPTER V

ALTERNATIVES

Alternatives considered for the tar sands research by LERC are:

--No action

--Increased action

--Maintain status quo.

The no action alternative is feasible if ongoing research results in the conclusion that the recovery of oil from tar sands by in situ technology is not feasible.

The increased action alternative is feasible if present research is successful and if economics will support further research.

Maintaining present research levels may be wise if ongoing research does not reveal any strong advantages for accelerating research.

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APPENDIX A
BIRDS OF SAGEBRUSH-TYPE HABITATS

APPENDIX A

Birds of Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	Blackford 1956	VTN 1975
Malard			
<u>Anus platyrhynchos</u>			X
Turkey Vulture			
<u>Cathartes aura</u>		X	X
Cooper's Hawk			
<u>Accipiter cooperii</u>			X
Red-Tailed Hawk			
<u>Buteo jamaicensis</u>		X	X
Swainson's Hawk			
<u>Buteo swainsoni</u>		X	
Ferruginous Hawk			
<u>Buteo regalis</u>	X	X	
Golden Eagle			
<u>Aquila chrysaetos</u>		X	X
Marsh Hawk			
<u>Circus cyaneus</u>		X	X
Prairie Falcon			
<u>Falco mexicanus</u>		X	X
American Kestrel (Spar Hk)			
<u>Falco sparverius</u>		X	X
Sage Grouse			
<u>Centrocercus urophasianus</u>		X	
Upland Sandpiper (Plover)			
<u>Bartramia longicauda</u>	X		
Mourning Dove			
<u>Zenaidura macroura</u>	X	X	X
Great Horned Owl			
<u>Bubo virginianus</u>		X	
Burrowing Owl			
<u>Speotyto cunicularia</u>	X	X	
Long-eared Owl			
<u>Asio otus</u>		X	
Poorwil			
<u>Phalaenoptilus nuttallii</u>		X	
Common Nighthawk			
<u>Chordeiles minor</u>	X	X	X
White-throated Swift			
<u>Acronautes saxatalis</u>			X

APPENDIX A--CONTINUED

Birds of Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	Blackford 1956	VTN 1975
Broad-tailed Hummingbird			
<u>Selasphorus platycercus</u>			X
Common Flicker			
<u>Colaptes cafer</u>			X
Eastern Kingbird			
<u>Tyrannus tyrannus</u>	X		
Western Kingbird			
<u>Tyrannus verticalis</u>	X	X	X
Cassin's Kingbird			
<u>Tyrannus vociferans</u>	X		
Ash-throated Flycatcher			
<u>Myiarchus cinerascens</u>			X
Say's Phoebe			
<u>Sayornis saya</u>		X	X
Willow (Traill's) Flycatcher			
<u>Empidonax traillii</u>			X
Gray Flycatcher			
<u>Empidonax wrightii</u>		X	X
Horned Lark			
<u>Eremophila alpestris</u>		X	X
Violet-Green Swallow			
<u>Tachycineta thalassina</u>			X
Rough-winged Swallow			
<u>Stelgidopteryx ruficollis</u>			X
Cliff Swallow			
<u>Petrochelidon pyrrhonota</u>			X
Scrub Jay			
<u>Aphelocoma coerulescens</u>		X	X
Black-billed Magpie			
<u>Pica pica</u>			X
Common Raven			
<u>Corvus brachyrhynchos</u>		X	X
Pinon Jay			
<u>Gymnorhinus cyanocephala</u>	X	X	X
Plain Titmouse			
<u>Paus inornatus</u>	X		X
Bushtit			
<u>Psaltipagus minimus</u>	X		
Bewick's Wren			
<u>Thryomanes bewickii</u>	X		

APPENDIX A--CONTINUED

Birds of Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	Blackford 1956	VTN 1975
Canyon Wren			
<u>Catherpes mexicanus</u>			X
Rock Wren			
<u>Salpinctes obsoletus</u>			X
Brown Thasher			
<u>Toxosfoma rufum</u>	X		
Sage Thasher			
<u>Oreoscoptes montanus</u>	X	X	X
American Robin			
<u>Turdus migratorius</u>			X
Mountain Bluebird			
<u>Sialia currucoides</u>			X
Blue-gray Gnatcatcher			
<u>Podioptila caerulea</u>	X		X
Loggerhead Shrike			
<u>Lanius ludovicianus</u>	X	X	X
Virginia's Warbler			
<u>Vermivora virginiae</u>			X
Yellow Warbler			
<u>Dendroica petechia</u>			X
Yellow Rumped Warber			
(Audubon's and Myrtle)			
<u>Dendroica coronata</u>			X
Black-throated Gray Warbler			
<u>Dendroica nigrescens</u>			X
MacGillivray's Warbler			
<u>Oporornis tolmiei</u>			X
Wilson's Warbler			
<u>Wilsonia pusilla</u>			X
Western Meadowlark			
<u>Sturnella neglecta</u>	X	X	
Redwinded Blackbird			
<u>Agelaius phoeniceus</u>			X
Brewer's Blackbird			
<u>Euphagus cyanocephalus</u>			X
Brown-headed Cowbird			
<u>Molothrus ater</u>			X
Western Tanager			
<u>Piranga ludoviciana</u>			X
Lizuli Bunting			
<u>Passerina amoena</u>	X	X	

APPENDIX A--CONTINUED

Birds of Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	Blackford 1956	VTN 1975
Dickcissel			
<u>Spiza americana</u>	X		
House Finch			
<u>Carpodacus mexicanus</u>	X	X	X
Green-tailed Towhee			
<u>Chlorura chloura</u>		X	X
Rufous-Sided Towhee			
<u>Pipila erythrophthalmus</u>		X	X
Lark Bunting			
<u>Calamospiza melanocorys</u>	X	X	
Grasshopper Sparrow			
<u>Chondestes gramineus</u>	X		
Vesper Sparrow			
<u>Poocetis gramineus</u>	X		
Lark Sparrow			
<u>Chondestes gramineus</u>	X	X	X
Black-throated Sparrow			
<u>Amphispiza bilineata</u>		X	X
Sage Sparrow			
<u>Amphispiza belli</u>	X	X	X
Chipping Sparrow			
<u>Spizella passerina</u>		X	X
Clay-colored Sparrow			
<u>Spizella pallida</u>		X	
Brewer's Sparrow			
<u>Spizella breweri</u>	X	X	X
White-crowned Sparrow			
<u>Zonotrichia leucophrys</u>			X

APPENDIX B

MAMMALS FOUND IN SAGEBRUSH-TYPE HABITATS

APPENDIX B

Mammals Found in Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	BLM 1971	VTN 1975
Merrian's Shrew			
<u>Sorex palustrus</u>		X	
Long-legged Myotis			
<u>Myotis volans</u>	X	X	
Little Brown Myotis			
<u>Myotis lucifugus</u>		X	
Long-eared Myotis			
<u>Myotis evotis</u>	X	X	
Fringed Myotis			
<u>Myotis thysandose</u>		X	
Small-Footed Myotis			
<u>Myotis subulatus</u>	X	X	
Silver-Haired Bat			
<u>Lasionycteris noctivagans</u>		X	
Big Brown Bat			
<u>Eptesicus fuscus</u>	X	X	
Hoary Bat			
<u>Lasiurus cinereus</u>		X	
Spotted Bat			
<u>Euderma maculatum</u>		X	
Townsend's Big-Eared Bat			
<u>Corynorhinus townsendii</u>		X	
Western Pipistrel Bat			
<u>Pipistrellus hesperus</u>			X
Pallid Bat			
<u>Antrozous pallidus</u>		X	
Nuttall's Cottontail			
<u>Sylvilagus Nuttalli</u>	X		
Desert Cottontail			
<u>Sylvilagus audubonii</u>	X	X	X
White-Tailed Jack Rabbit			
<u>Lepus Townsendii</u>		X	
Whitetailed Antelope Squirrel			
<u>Ammospermophilus leucurus</u>			X
Golden Mantled Squirrel			
<u>Citellus lateralis</u>		X	X
Least Chipmunk			
<u>Eutamias minimus</u>	X	X	X

APPENDIX B

Mammals Found in Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	BLM 1971	VTN 1975
Colorado Chipmunk <u>Eutamias quadri vittatus</u>			X
Thirteen-Lined Ground Squirrel <u>Spermophilus tridecemlineatus</u>		X	
White-Tailed Prairie Dog <u>Cynomys leucurus</u>		X	X
Northern Pocket Gopher <u>Thomomys talpoides</u>	X	X	
Silky Pocket Mouse <u>Perognathus flaxus</u>	X		
Apache Pocket Mouse <u>Perognathus apache</u>			X
Ord's Kangaroo Rat <u>Dipodomys ordi</u>	X	X	X
Western Harvest Mouse <u>Reithrodontomys megalotis</u>	X	X	X
Deer Mouse <u>Peromyscus maniculatus</u>	X	X	X
Northern Grasshopper Mouse <u>Onychomys leucogaster</u>	X	X	
Desert Woodrat <u>Neotoma lipida</u>			X
Mountain Vole <u>Microtus montanus</u>		X	
Long-Tailed Vole <u>Microtus longicaudus</u>		X	
Sagebrush Vole <u>Lagurus curtatus</u>		X	
Coyote <u>Canis latrans</u>	X	X	X
Swift fox <u>Vulpes velox</u>	X	X	
Weasel <u>Mustela sp.</u>			X
Black-Footed Ferret <u>Mustela nigripes</u>	X		
Badger <u>Taxidea taxus</u>	X	X	
Spotted Skunk <u>Spilogale gracilis</u>	X	X	

APPENDIX B

Mammals Found in Sagebrush-Type Habitats

Species	Inventories		
	Cary 1917	BLM 1971	VTN 1975
Striped Skunk <u>Mephitis mephitis</u>		X	
Bobcat <u>Lynx rufus</u>		X	
Mule Deer <u>Odocoileus hemionus</u>		X	X